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DEGREE: Master of Science

YEAR THIS DEGREE GRANTED: 2001

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Effects of Cattle and Wild Ungulate Foraging on Trembling Aspen Regeneration in Alberta's Lower Boreal Forest

by

Craig William Morrison Dockrill ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

in

Rangeland and Wildlife Resources

Department of Agricultural, Food and Nutritional Sciences

Edmonton, Alberta

Fall 2001

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled ***Effects of Cattle and Wild Ungulate Foraging on Trembling Aspen Regeneration in Alberta's Lower Boreal Forest*** submitted by **Craig William Morrison Dockrill** in partial fulfillment of the requirements for the degree of **Master of Science in Rangeland and Wildlife Resources.**

ABSTRACT

This study sought to ascertain the effects of cattle and wild ungulate foraging on trembling aspen (*Populus tremuloides*) regeneration in Alberta's lower boreal forest. Wild ungulate foraging and eight levels of cattle foraging were examined.

Wild ungulate browsing did not affect aspen regeneration. Aspen regeneration was most successful in the absence of cattle. Grazing of cut-blocks by cattle during August-September was also compatible with aspen regeneration. Annual cattle grazing for four (1-year deferral) or five years reduced aspen stem height within June-July grazed treatments, thus impeding aspen regeneration.

June grazing increased aspen wounding and mortality rates relative to July grazing. Aspen stems were most susceptible to cattle damage during June, when resistance to shearing force was lowest. Resistance of aspen stems to shearing force increased throughout the growing season. Deferring cattle grazing until July improved aspen regeneration; by then aspen stems were less likely to be foraged by cattle.

ACKNOWLEDGEMENTS

I wish to begin by extending my thanks to my academic supervisor and friend, Dr. Art Bailey for his compassion and understanding over the duration of my study period. His guidance and support, both academically and personally were of great importance to me in completing this project. I would also like to thank Dr. Jane King, Dr. Stephen Titus, and Dr. Peter Blenis for their wisdom, guidance and critical thought in reviewing my thesis. I thank Dr. Jane King for her enthusiasm in becoming my co-supervisor at the time of Dr. Art Bailey's retirement. I owe Dr. Blenis a debt of gratitude for his infinite patience and generosity in helping with data analysis. Many thanks are also owed to my friend Dr. Barry Irving for his pragmatism, contributions to my field methods, and critical analysis of my thesis prior to the defense. Finally, I would like to thank Dr. Buncha Ooraikul for his proficiency in chairing the thesis defense, keeping all of us relaxed and on topic.

I would like to thank Weyerhaueser Canada Ltd., Westman Farms Ltd., Natural Sciences and Engineering Research Council, and Alberta Environment for providing the financial support required in order to execute this research project. Special recognition goes to Weyerhaueser Canada and Westman Farms for their cooperation with the goals of this project.

I would like to thank my dear friends Jeremy Forest, Scott Rohatyn, Erin Dale, Krista Polukoshko, Cindi Isaac, Shannon Hayes, Tiffany Billey and Jason Spady for their assistance with field and laboratory studies. I would especially like to thank Jeremy Forest for his industriousness, creativity, humour and great friendship while assisting with the construction of fences and collection of data. Further, I would like to thank

Zygmunt Misztal for providing me with invaluable meteorogical data from Shining Bank Weather Station. I am also thankful to Bernie Faulkner and Ian Buttar of the Mechanical Engineering Department for their assistance with shearing force measurements.

Among the many opportunities presented to me during graduate school, the greatest has been the chance to meet and know Amanda Joynt. For your warmth, love and radiant smile I am greatly indebted. Countless days of frustration and angst have been washed away by a single smile from you.

For their unconditional love and many sacrifices I would like to thank my parents, Linda and Ernest. Without their encouragement my academic pursuits would have ceased long ago. Thank you for instilling in me the importance of diligence, perseverance and understanding.

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LIST OF NOMENCLATURE AND ABBREVIATIONS

Deciduous Timber License (DTL) – a license granting a company the right to harvest forest within a given area on provincial crown land.

Forest Grazing Lease (FGL) – a contract between the provincial government and a private livestock producer, granting that producer the right to utilize forage resource on forested crown land between June 1 and September 30 of each growing season. Leases continue in perpetuity providing that the integrity of plant communities within a lease area are not adversely affected by specific grazing practices.

Graminoid – refers to plants of the family Gramineae; grasses.

Slash – the debris left behind by harvesting operations.

Ungulate – a hoofed animal; includes members of the cattle, deer, and antelope families.

Populus – in this document refers to the aggregate of *Populus tremuloides* and *Populus balsamifera* measurements.

Early Season Grazing (ESG) – Areas grazed between June 1 and July 30 of each growing season.

Late Season Grazing (LSG) – Areas grazed between August 1 and September 30 of each growing season.

1.0 INTRODUCTION

1.1 Background Information

Historically, Alberta's trembling aspen (*Populus tremuloides* Michx.) dominated forests have been valued primarily for recreation opportunities, watershed functions, wildlife habitat, and forage production. Grazing dispositions, issued to cattle producers as an economical source of summer forage preceded other industry uses of aspen forests. During the past two decades, advents in technology and access to new markets have radically changed the socioeconomic landscape of aspen forests in Alberta. Multiple land-use conflicts in these areas have increased dramatically with the addition of two resource extracting industries: petroleum and forestry. In the aspen-dominated Lower Boreal Cordilleran Ecoregion of Alberta (Strong and Leggat 1992), conflicts between livestock producers and timber/fiber producers are most prevalent.

Increasing demand for wood fiber, and technological advances in wood fiber processing has created a highly profitable aspen harvesting industry (Peterson and Peterson 1992). Trembling aspen and balsam poplar *(Populus balsamifera* L.) are now used in the production of Oriented Strand Board (OSB), pulp, lumber, and numerous specialty products. Harvest of *Populus* species near Whitecourt, Alberta began in 1982 for OSB, expanded in 1986, expanded in 1987 for pulp production, and expanded yet again in 1989 (Darrah 1991). Approximately 35 000 hectares of Alberta's hardwood and mixedwood forests were harvested during 1998 (Anonymous 2000 c).

New demands for aspen timber motivated Alberta's government to issue Deciduous Timber Licenses (DTLs) to forestry companies. Eventually, some timber licenses came to overlap preexisting Forest Grazing Leases (FGLs) issued to livestock

producers for summer grazing (Lane 1998). Competition between livestock producers and timber producers for Alberta's resource-rich landscapes soon created conflicts.

Multiple land-use policy, as promoted by Alberta's provincial government deems crown land a resource that should be utilized to its best and maximum capacity (Anonymous 2000 b). Although relatively new in Alberta, integrated timber harvest and livestock production has existed for hundreds of years (Watkins 1989). On private land, multiple-use provides flexibility and stability of income (Lundgren et al. 1983). However in Alberta, livestock production and timber harvesting overlap primarily on crown lands, where 87% of forest ecosystems occur (Anonymous 2000 c).

1.1.1 Conflicting Views

Traditionally, livestock producers and forest companies operated independently on landscapes designated for a single economic purpose. In such systems resource users could employ singular objectives and methods. In Alberta, many cattle producers realize the need for affordable summer forage by utilizing sustainable forage supplies on leased crown land between June 1st and September 30th of each calendar year. Timber producers strive to maximize annual allowable cuts and forest regeneration; sometimes investing large sums of capital and resources in the process. However, multiple-use landscapes necessitate a change in attitude for all resource users such that the objectives and needs of other user groups are considered. Mutual depreciation of differing objectives combined with an unwillingness or inability to apply multiple use and proper use principles perpetuates conflicts between cattle producers and forest companies (Nordstrom 1984).

Forest companies are concerned that poor stand regeneration may result from trampling and foraging of seedlings by cattle in cut-blocks (McLean and Clark 1980). In

this study area, the forest company contends that grazing of cut-blocks by cattle impedes trembling aspen growth, jeopardizing the ability of stands to meet establishment and regeneration standards. Alberta's provincial government sets very specific targets for forest regeneration (Anonymous 2000 a). In deciduous cut-blocks of the Lower Foothills Subregion acceptable trees will be ≥ 3 years of age, alive, healthy, undamaged, and ≥ 80 centimeters in height at 3-5 years post-harvest. In addition, satisfactorily restocked areas will have 7000 acceptable deciduous trees per hectare with an average height of 140 centimeters. If forest establishment or regeneration standards are not met, a forest company can face financial penalties, a contentious policy where livestock activity is perceived to limit aspen regeneration.

Livestock producers contend that clear-cut harvesting methods impede aspen regeneration while silvicultural prescriptions disregard the need for sustainable summer forage resources. Although clear-cutting offers potential for short-term increases in forage production, dense deciduous re-growth can reduce livestock access and limit grazing distribution (Wheeler and Willoughby 1993). Herbaceous forage production in mature forests is dramatically lower than in open meadows (Jonhston and Smoliak 1968); a potential threat to long-term stability of forage resources. The following guidelines regarding timber harvest on grazing dispositions are designed to address conflicts between forest companies and livestock producers (Alberta Environmental Protection 1994):

1. On grazing dispositions, timber operators shall consult with grazing disposition holders to address specific concerns before operations begin.

2. During harvest, hauling, reforestation and reclamation operations, timber operators shall ensure that existing roads, bridges or improvements to active grazing dispositions are maintained.
3. Timber operators shall ensure that timber operations do not reduce carrying capacity of the range for domestic livestock grazing.
4. Grazing disposition holders will be advised by the timber operator at least 10 days before operations begin on timber dispositions affecting grazing dispositions.

Provincial regulations address short-term conflicts, but fail to alleviate the concerns of livestock producers regarding sustainable forage and forest companies regarding successful forest regeneration in multiple-use landscapes.

Potential cattle damage to conifer seedlings has been studied extensively in North America (Hall et al. 1992, Kingery and Graham 1991, Eissenstat et al. 1982, Clark and McLean 1978, 1974). Conversely, investigation of cattle impacts on regenerating aspen stands in Alberta's boreal forest is incomplete. Consequently, knowledge gaps persist regarding ecology; stand management, stand renewal, and cooperative management of aspen forests (Peterson and Peterson 1992). A polarization of views has created a conflict between Alberta's two largest renewable resource industries. This conflict is exacerbated by public concern regarding the ecological implications of cattle grazing and timber harvesting within the boreal forest of Alberta.

1.1.2 Purpose of Study

The general goal of this study is to determine the effect of cattle grazing, wild ungulate browsing, and cumulative cattle and wild ungulate foraging on trembling aspen regeneration in Alberta's Lower Boreal Cordilleran Ecoregion. To that end, three complementary studies involving management of ungulate foraging with exclosure fencing will be implemented. Wild ungulate foraging will be examined in one study,

while the effects of cattle foraging will be examined in two additional studies. The first cattle grazing study will examine the effects of entire growing season deferrals within June-July and August-September grazing systems on aspen regeneration during the first five years post-harvest. The second cattle grazing study will examine the effects of single month deferrals within a June-July grazing system during the fourth and fifth years post-harvest. One additional laboratory study will be undertaken to assess the resistance of aspen stems to shearing force during the fourth and fifth growing seasons post-harvest. These studies will provide information addressing the following questions:

1. How many growing seasons must cattle grazing be deferred following aspen stand harvest in order to assure successful regeneration of aspen stands?
2. Is season of cattle grazing (June-July vs. August-September) important in determining whether or not aspen stands can be successfully established following stand harvest in multiple-use landscapes?
3. Is there a critical growing season period (month) during which aspen stems are most impacted by cattle foraging activities?
4. Is rate of ungulate damage to young trembling aspen stem parts related to the ease with which ungulates can prehend stem parts?

It is hoped that the answers to these questions will aid the livestock producer, forest company and public land manager in deciding how to best integrate cattle grazing and forest harvest in a multiple-use landscape.

1.1.3 Project History

During the summer of 1994, six cut-blocks were harvested using full-tree skidding in accordance with Alberta Timber Harvest Planning and Operating Ground Rules (1994) and Weyerhaeuser's 1994 Annual Operating Plan (Lane 1998). The study site was comprised of 9 km^2 of the 23 km^2 Westman Farms Grazing Lease.

In 1995, two independent studies were initiated to assess the relationships between aspen harvesting/regeneration and cattle grazing within the Lower Boreal Cordilleran Ecoregion of Alberta. One study: "The effects of full-tree skidding and cattle grazing on aspen regeneration", was completed by Cameron Lane in 1996. At two-years post harvest, Lane (1998) reported the following:

1. In the absence of livestock grazing, higher skidding intensity reduces aspen density, stem height, stem diameter, and total biomass.
2. At two years post-harvest there is no clear indication that cumulative effects of livestock grazing and skidding operations will affect long-term sustainability of timber and forage production.
3. Livestock grazing is most detrimental on skid disturbances with the greatest aspen productivity following stand harvest.
4. Livestock impacts on aspen regeneration are more pronounced in June-July (early season) than August-September (late season).

A five-year study: "The effects of deferred cattle and wild ungulate foraging on post-harvest aspen regeneration and forage production" was continued through to 1999. Findings from the second study are contained in the remainder of this thesis; results at two years post-harvest (Leoppky unpublished data) suggest the following:

1. Grazing of cut-blocks by cattle is more detrimental to aspen regeneration during June-July than August-September.
2. Treatments given no deferral of cattle grazing show poorer regeneration than treatments subject to 1-year or permanent deferral of cattle grazing.
3. Effects of wild ungulate foraging in the presence of cattle is minimal.
4. Cattle distribution is correlated with ease of access, while wild ungulate distribution is correlated with proximity of forest cover.

Studies of cattle and wild ungulate foraging initiated in 1995 were continued each year through to 1999; new additions to the study were made during the spring of 1998, at four years post-harvest.

1.2 Associated Research - Aspen Regeneration

Members of the genus *Populus* are able to reproduce sexually by seed or asexually by vegetative root suckers. Vegetative propagation provides trembling aspen and balsam poplar with a competitive advantage over conifer species in boreal mixed-wood stands (Peterson and Peterson 1992). Vegetative sucker and seed reproduction are not temporally or spatially exclusive, although they are often addressed independently in scientific research. Trembling aspen is quick to mature, producing flowers at the relatively young age of 10-15 years (Maini 1968). Despite early seed production, sexual reproduction of aspen is limited by very specific seedbed requirements for germination. Trembling aspen seedlings are extremely sensitive to environmental gradients including soil temperature and soil moisture, thus root suckering is responsible for the majority of productive aspen stands.

Vegetative reproduction in *Populus* species is initiated by disruption of apical dominance, and promoted by greater soil temperatures (Peterson and Peterson 1992). Beyond these two requisites, many factors enhance or reduce vegetative suckering: soil characteristics (Maini and Horton 1966, 1964), pre-harvest stand and root characteristics (Kemperman 1978, Maini 1967, Horton and Maini 1964) and hormone regulation (Schier 1976, Steneker 1972, Farmer 1962). Ultimately, the establishment of a healthy trembling aspen stand is dependent upon a diverse matrix of environmental parameters.

1.2.1 Forest Harvest and Stand Disturbance

Stand disturbance often determines abundance of aspen sucker propagation (Peterson and Peterson 1992). In Alberta's managed forests, the most common sources of stand disturbance are fire and tree harvest (Anonymous 2000 c), which can vary from high-grade logging on private woodlots to clear-cut logging in commercial forests. Healthy, well-stocked aspen stands can be harvested by numerous means, at various periods throughout the year with reasonable assurance that a sucker stand will follow (Steneker 1976). Promoting full suckering in recently logged aspen stands requires disruption of apical dominance, thus clear-cut logging should be most effective (Schier 1981). Several clear-cut harvest techniques are acceptable for aspen forests, including skidding of entire trees and short form length skidding (Zasada 1972). While different harvesting methods have various effects on the regenerative capacity of a stand, ensuring successful regeneration may depend upon controlling inter-specific competition (Perala 1972).

Harvesting of aspen stands during winter months, when trees are dormant results in maximum suckering during the subsequent growing season, but at 3 years post-harvest evidence of seasonal harvest impacts are minimal (Peterson and Peterson 1992). Winter harvesting also reduces soil compaction and promotes uniform sucker emergence. Conversely, summer harvesting is more destructive to under-story vegetation, reducing inter-specific competition with aspen suckers (Bella 1986). However, skidding traffic can reduce aspen suckering by injuring shallow lateral parent roots, or via soil compaction and root mortality (Shepperd 1993). Areas adjacent to logging roads, areas of heavy skidding, and associated decking areas comprise up to 19% of a clear-cut

harvest operation by area, and show reduced aspen suckering (Lane 1998). Forest harvesting methods that inhibit trembling aspen regeneration can be ameliorated by winter logging, which protects soil mediums and reduces root damage. However, economic forces, available equipment and biological factors influence harvest schedules and methods (Jones and Shepperd 1985), which must be applied on a site-specific basis.

1.2.2 Parental Root Systems and Suckering Ability

Potential for aspen stands to produce vegetative suckers depends upon pre-disturbance state of parental root systems, stand age, site characteristics, and clonal variation (Peterson and Peterson 1992). Decadent or aging aspen stands can exhibit root decay, thereby reducing suckering potential (Steneker 1976). Aspen roots typically grow in a series of widely spreading lateral roots, vertical roots originating at the tree base, and sinker roots that descend from lateral roots (Peterson and Peterson 1992). Four or five lateral roots originate from a stem base and form an intertwining series of cord-like roots. Some of these roots extend great distances without a reduction in diameter, and are usually excellent candidates for sucker production (Maini 1960). Sinker and vertical roots are known to reach depths in excess of 2.7 meters (Gifford 1966), while lateral roots are most abundant in the upper 25 centimeters of soil (Strong and La Roi 1983). Aspen suckers are borne out of lateral roots in the upper soil profile, illustrating the importance of protecting soil substrates during forest harvest operations to ensure vigorous aspen regeneration.

1.2.3 Soil Properties

Trembling aspen stands occur on a variety of sites, but achieve their best growth on well-drained uplands (Haeussler and Coates 1986). Although aspen can survive

extended periods of flooding, productivity declines (Corns 1989). Soil moisture is a function of soil texture and porosity (Peterson and Peterson 1992), and is reported as the single most important factor affecting aspen growth (Fralish 1972). On sites with consistently wetter soils, balsam poplar often replaces trembling aspen as the dominant tree species.

Soil temperature can also affect aspen regeneration. Initiation of aspen suckers is inhibited by cold soils (Zasada and Schier 1973). Soil temperatures <6°C greatly reduce growth of trembling aspen roots, shoots, and leaves (Landhausser and Lieffers 1998). Maximum aspen sucker production occurs when soil temperatures reach or exceed 20°C (Steneker 1976).

1.2.4 Hormone Regulation

Greater soil temperatures promote aspen suckering by lowering auxin levels and stimulating production of cytokinin (Williams 1972). Hormonal relationships within the parental root system determine aspen sucker initiation. Apical dominance of aspen trees is maintained by translocation of auxin from the crown to the roots via the phloem, inhibiting sucker propagation (Schier 1976, Farmer 1962). Conversely, cytokinin produced in the roots is responsible for sucker emergence and growth (Peterson 1975). Cytokinin:auxin ratios present in aspen root systems determines whether or not suckering is promoted or suppressed. If cytokinin:auxin ratios are low, suckering is suppressed (Wilter 1968). Removal of apical dominance of trees by harvesting, fire, or girdling disrupts the flow of auxin to root systems and elevates cytokinin:auxin ratios, stimulating sucker growth (Shier 1974).

1.2.5 Inter-Specific Competition

Inter-specific competition can limit the growth of young trees (Landhausser and Lieffers 1998, Peterson 1988, Eis 1981). Considerable reductions in lodgepole pine (*Pinus* contortus) seedling growth and survival occur as grass densities increase (Clark and McLean 1975). Lodgepole pine obtains maximum volumes in the presence of grazing, and absence of graminoid seeding during post harvest management (McLean et al 1986). Ponderosa pine (*Pinus ponderosa*) seedlings grow faster in the presence of grazing than do seedlings in the absence of grazing (Karl and Doescher 1993). These studies suggest that grazing promotes the growth of young trees by reducing inter-specific competition. In the absence of site preparation, control of competing vegetation is important, particularly on nutrient rich sites where graminoid species are abundant (Shelton and Murphy 1994).

1.3 Associated Research - Ungulate Foraging

The forest company favours exclusion of domestic ungulates from regenerating forests because ungulates can damage young trees. Ungulate damage to trees most often occurs in one of three manners: stripping of leaves, browsing of terminal and/or lateral shoots, and incidental trampling of stems. Trees that are damaged by herbivores exhibit reduced stem heights (Kingery and Graham 1991). Cattle stocking rate, grazing distribution and season of grazing are key management issues to be considered in livestock-forestry systems (Ratliff and Denton 1995). Proper management of livestock within cut-blocks may reduce the incidence of ungulate damage to trees.

1.3.1 Distribution of Ungulates in Cut-blocks

Ungulate foraging behaviour is greatly affected by harvesting methods and post-harvest stand management. Forests present a variety of plant communities, habitats, and foraging opportunities for both domestic and wild ungulates. Cattle utilize cut-blocks throughout the growing season (May – October), wapiti (*Cervus elaphus*) prefer cut-blocks during spring and early summer prior to utilization by cattle, while deer (*Odocoileus* spp.) avoid cut-blocks instead using forest edges as primary foraging habitat (Roscoe and Kingery 1989). Forest landscapes can influence animal distribution through provision of thermal cover, escape cover, and water. Distribution of cattle is strongly correlated with ease of access (Leoppky unpublished data); cattle are expected to congregate along roads and in cut-blocks where physical obstructions are minimal.

Logging roads and presence/absence of slash can affect livestock access, altering grazing patterns and forage utilization (Nordstrom 1984, Edgerton 1971). Logging roads are primary cattle access routes within cut-blocks and cattle may return to roads during non-grazing periods (Roath and Krueger 1982). Cattle grazing pressure is inversely related to distance from roads; forage utilization is greater near roads than in areas distanced from roads (Leoppky unpublished data). Without uniform distribution of grazing pressure poor range condition can result.

Cattle foraging behaviour is affected by ambient temperature, precipitation, evapotranspiration and available habitat. In drier years cattle spend more time under the forest canopy, showing strong preference for understory vegetation due to its relatively high moisture content (Hilton and Bailey 1972). Time spent under canopy cover is also

related to ambient temperature, as cattle seek relief from heat in open forests that offer a combination of shade and forage resources (Mitchell and Rodgers 1985).

Forest grazing systems can parallel pastoral grazing systems in their availability and attractiveness of water to cattle. Cattle show a high preference for areas proximal to riparian zones spending approximately 35% of their time within 100 meters of water sources (2-5% of area) (Kie and Boroski 1996). In prairie landscapes, forage resources proximate to water are grazed more heavily and earlier than forage resources further from water (Irving et al. 1995). Propensity of cattle for riparian areas causes localized overgrazing and distribution problems in pastoral systems. However, boreal forest ecosystems can provide ephemeral water sources during periods of greater precipitation as alternatives to riparian zones and thus alter foraging behaviour.

1.3.2 Cattle Grazing

Trembling aspen is an important source of forage for domestic livestock (Bailey 1981), due to the expansion of beef cattle production into southern portions of Alberta's boreal forest. Depending on grazing pressure and stocking rates, cattle have the potential to reduce aspen growth (Jones 1983). Previous studies in Alberta indicate that grazing of aspen forests by cattle does not affect stand regeneration (Sundquist 1995, Wheeler and Willoughby 1993, Weatherhill and Keith 1969).

Grazing of forested landscapes by cattle is reported to enhance the growth of young trees (Huntsinger 1996, Ratliff and Denton 1995, Clark and McLean 1979). Potential benefits of grazing to tree seedlings include: more favorable site conditions and improved growth rates. Conifer seedlings show better growth rates with grazing than without grazing (Ratliff and Denton 1995). Available nitrogen is higher on grazed

Monterey pine (*Pinus radiata*) sites than in the absence of grazing (Clinton and Mead 1994). In addition, soil water differences between grazed and ungrazed plots in Douglas fir-Ponderosa pine forest types are reported as negligible (Karl and Doescher 1993).

Reduction of inter-specific competition can significantly impact seedling/sucker growth rates and may be the most critical role for ungulates to play in regenerating forests. Grazing can reduce biomass of competitive species and competitor propagation through removal of seeds (Clark and McLean 1979). Grazing can also dramatically reduce root expansion of grass species such as orchardgrass (*Dactylis glomerata*) (Karl and Doescher 1993). Although existing research regarding the benefits of grazing animals on forest regeneration focuses upon conifer species, there is no reason to believe similar benefits cannot be accrued by trembling aspen suckers.

Among other merchantable tree species, studies show that cattle grazing can also impede seedling growth (Kingery and Graham 1991, Eissenstat et al. 1982). Douglas fir (*Pseudotsuga menziesii*) seedlings are often preferred over understory species, some of which have low palatability and nutritive value (Karl and Doescher 1993). A majority of Scots pine (*Pinus sylvestris*) seedling damage results from cattle trampling and occurs within two years post-planting while trees are less than 30 cm in height (Kingery and Graham 1991). Douglas fir seedlings are most susceptible to trampling during their first year post-planting while they are also less than 30 cm in height: 76% mortality in the presence of cattle versus 36% mortality in the absence of cattle (Eissenstat et al. 1982). It is apparent that young trees, particularly those less than 30 cm in height may be more susceptible to cattle damage; deferral of cattle for one or more growing seasons could improve stand regeneration.

If domestic ungulate damage to young trees is minimized, the use of grazing for competition control could prove advantageous over chemical and mechanical control methods (Popay and Field 1996). While there are many seedling growth benefits associated with livestock grazing, most existing information pertains to conifer seedling plantations. The potential benefits associated with cattle grazing in regenerating forests must be considered on a site-specific basis because ecology, biology and management factors vary greatly between forest types.

1.3.3 Seasonal Grazing

Season of use is a primary determinant of whether or not cattle grazing benefits or harms regenerating trembling aspen stands. Season of grazing is cited as more detrimental to seedling growth and survival than grazing intensity or density of grazing animals, with dormant season grazing being least detrimental to young trees (Hall et al. 1992). Cattle foraging preferences and ability of vegetative species to persist under grazing pressure varies throughout the growing season (Lane 1998). Cattle are reported to prefer grasses early in the growing season and delay consumption of aspen shoots and leaves until after herbaceous forage is depleted (Fitzgerald and Bailey 1984). Late season grazing causes a shift in cattle preferences and aspen is selected over mature grass, reducing aspen stem height, and growth in the following year. Evidence of seasonal foraging effects on seedling survival implies that Alberta's crown land grazing leases, which operate through the short four-month summer growing season could render young trees vulnerable to foraging damage.

1.3.4 Wild Ungulate Browsing

While the debate regarding the extent of cattle impacts on regenerating aspen forests continues, many people ignore the fact that cattle are not exclusively responsible for damage sustained by aspen suckers. Wild ungulates have continuous access to forage resources, whereas cattle have access to aspen suckers between June 1st and September 30th of each growing season. It is likely that summer utilization of aspen stems results from cattle, whereas autumn, winter and spring browsing of aspen results from wild ungulates (Rangen and Roy 1997). Aspen seedling/sucker growth and survival can be affected by the browsing activities of various wild herbivores (DeByle and Winokur 1985). Indigenous herbivores of the Lower Boreal Cordilleran Ecoregion are moose (*Alces alces*), wapiti and deer; collectively known as cervids. However, smaller herbivores such as snowshoe hares (*Lepus americanus*) are often overlooked as sources of browsing damage.

Extensive browsing by elk, moose and deer can have an equal or greater impact on regeneration potential of aspen forests than cattle foraging (Graham and Kingery 1990). Deer browsing in small clear-cuts can prevent aspen regeneration (Mueggler and Bartos 1977), while winter elk browsing can also reduce aspen stands (Krebill 1972, Graham et al. 1963). Moose are known to break down young trees with diameters of up to 10 cm in order to access crown twigs, despite the presence of shorter trees (Telfer and Cairns 1978). Although most wild ungulate browsing occurs during winter, while trees are dormant, the potential for regeneration failure of aspen stands remains.

Small herbivorous mammals, such as snowshoe hare (*Lepus americanus*) and pocket gopher (*Thomomys talpoides*) may exacerbate browsing pressure on aspen stems.

Snowshoe hare foraging causes significant damage to lodgepole pine seedlings (Sullivan 1984), and hare preference for aspen (Bryant and Kuropa 1980) suggests the potential for similar impacts on regenerating aspen stands. Pocket gophers are reported to cause 71% of observed tree mortality, elk and deer 9%, and cattle just 4% (Graham and Kingery 1990). Fungi and insects are associated with 21% of documented tree deaths. Animal foraging damage to aspen stands is variable, complex and often of multiple origins, necessitating a thorough understanding of the foraging preferences of each herbivore present and how those herbivores interact.

1.3.5 Cumulative Cattle and Wild Ungulate Foraging

Dietary preferences are variable among ungulates and may be important in determining the success of trembling aspen regeneration in multiple-use landscapes. Cattle are known to consume early-succession graminoid species in highest proportions, while deer prefer forb and shrub species (Kingery et al 1996). Studies of cattle diets show that grass and forbs are preferred, but woody species are utilized when forage resources are limited (Hilton and Bailey 1974). Cattle utilize grass and forbs most frequently early in the growing season (29% of diet), while use of woody species increases to a maximum of 37% at the end of the growing season (Uresk and Paintner 1985). Cattle select woody forage species more readily after August 1st (Fitzgerald et al. 1986), with the following order of preference: raspberry (*Rubus idaeus*), wild rose (*Rosa woodsii*), trembling aspen (*Populous tremuloides*) and snowberry (*Symphoricarpos occidentales*). Similar to cattle, elk prefer grasses and forbs (Roscoe and Kingery 1989), but their diet can also vary with season.

Interactions between cattle and wild ungulates may affect the extent to which aspen suckers are utilized as a forage resource. Grazing, browsing and trampling by cattle and wild ungulates can impede aspen regeneration (Greenway 1990). Alberta's lower boreal forest provides excellent habitat for three wild ungulates: deer, elk, and moose, and hosts cattle herds of varying size during summer. Deer and elk foraging is inversely related to cattle stocking rate (Skovlin et al 1975), indicating that overgrazing by cattle can reduce forage resources for wild ungulates. Intensive cattle grazing of elk winter range can force elk to browse aspen suckers more frequently, to the detriment of aspen stand survival (DeByle and Winokur 1985). Cattle are known to have similar impacts on the browsing behaviour of deer, subsequently causing greater aspen damage (Julander 1955). Conversely, wild ungulate browsing has minimal impacts on summer forage supplies for cattle within this study area (Lane 1998). Reductions in aspen growth as a result of ungulate foraging could lead to sanctions against the forest company.

1.4 Experimental Area

1.4.1 Location

The experimental area was located approximately 200 kilometers northwest of Edmonton, Alberta, 53°39' North latitude, 115° 35' West longitude. Experiments were conducted on Westman Farms' Grazing Lease 16454 and Weyerhaueser Canada Ltd's Deciduous Timber License W050007, covering 23 square kilometers (Section 19-21, 28-30, Township 056, Range 11, West of the fifth meridian).

1.4.2 Macroclimate

The experimental area was located within the Lower Boreal Cordilleran Ecoregion of Alberta (Stong and Leggat 1992). The area has a continental climate,

characterized by warm summers and cold winters. Average annual precipitation is 464 millimeters, with two-thirds of that falling during summer months (Strong and Leggat 1992). Summer temperatures in combination with high precipitation create potential-evapotranspiration rates near zero from May through August.

1.4.3 Microclimate

Information on local climatic factors was taken from Shining Bank Weather Station (Alberta Environment 2000) approximately 30 kilometers west of the study area. Historical mean summer precipitation (April 1st to September 30th) is 395 millimeters, while mean summer temperature is 10.8°C. Mean summer precipitation was below historical means during 1995, 1998 and 1999 (Fig 1-1.), with the highest precipitation occurring during the summer of 1996. Mean summer temperature was highest during 1998 and lowest during 1996 (Fig 1-2). Topography is generally undulating and rolling with a maximum elevation of 980 meters and a minimum elevation of 860 meters above sea level. Drainage in the area is moderate to good, with slopes ranging from 2 to 9 percent.

1.4.4 Geology and Soil Formations

Parent material in the study area originates from the Paskapoo Formation of the Early Tertiary age, and was deposited by the Continental Ice Sheet (Twardy and Lindsay 1971). This underlying substrate consists of sandstone, shale, and coal. A majority of soils present are formed from materials deposited during and/or following glaciation. Most soils within the study area are Orthic Gray Luvisols or Eluviated Eutric Brunisols, belonging to the Hubalta and Codesa soil series. These soils are characterized as

moderately well drained clay loams, with low levels of organic matter and nutrients (Strong and Leggat 1992).

1.4.5 Vegetation Communities

The Lower Boreal Cordilleran Ecoregion of Alberta is an interface between deciduous and coniferous vegetation communities (Strong and Leggat 1992). Deciduous stands are dominated by trembling aspen, balsam poplar, and paper birch (*Betula payrifera*) and occupy lower lying areas. Coniferous communities are dominated by lodgepole pine, white spruce (*Picea glauca*) and black spruce (*Picea mariana*) and occupy higher positions in the landscape. Understory vegetation is comprised of the following species: hairy wild rye (*Elymus innovatus*), rose (*Rosa* spp.), fireweed (*Epilobium angustifolium*), wintergreen (*Pyrola* spp.), marsh reedgrass (*Calamagrostis canadensis*), and larbrador tea (*Ledum groenlandicum*) (Strong and Leggat 1992).

Mid-slope communities comprise 85% of the study area and are dominated by trembling apsen, balsam poplar, green alder (*Alnus crispa*), marsh reedgrass and various mosses (Willoughby 1994). Lower slopes comprise 10% of the study area and are characterized by trembling aspen, balsam poplar, river alder (*Alnus tenuifola*), green alder, and marsh reedgrass. The remaining areas are drier uplands, where plant communities are comprised of trembling aspen, balsam poplar, strawberry (*Fragaria virginiana*), and marsh reedgrass.

Forage production within the study area averages 1460 kilograms per hectare of mature aspen forest, but high concentrations of *Alnus* species may inhibit livestock utilization of forage resources (Sundquist et al. 1997). Forage production in cut-blocks varies with disturbance regime and plant community.

1.4.6 Wildlife Resources

Wildlife species present within the study area are numerous and diverse. Ungulate species include wapiti, moose, mule deer (*Odocoileus hemionus*), and white-tailed deer (*Odocoileus virginanus*). Other mammals in the area include black bear (*Ursus americanus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), snowshoe hares, and various members of the orders Mustelidae (Weasels) and Cricetidae (New World Mice).

1.4.7 Livestock Management

Prior to 1995, Westman Farms released approximately 100 cow/calf pairs onto the study site to forage between June 1st and September 30th. Following stand harvest in the summer of 1994, and in agreement with the goals of this research project some elementary management factors were implemented. A central fence was constructed to divide the forest grazing lease into halves. Cattle grazed one half of the lease during June-July each of the next five growing seasons, while the other half was grazed by cattle during August-September each of the next five growing seasons. Other pre-existing management practices were not altered. Range riders typically tended to the herd periodically throughout the growing season, and were responsible for herd movement at agreed upon intervals. Westman Farms also maintained perimeter fences around the forest grazing lease.

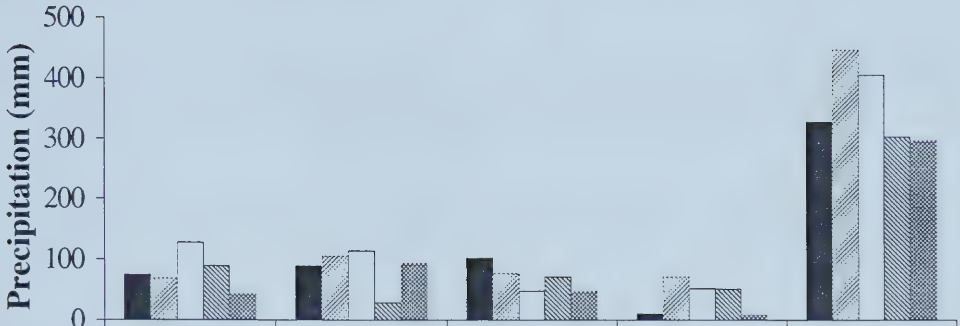
1.4.8 Forest Harvest Methodology and Timing

The forest harvest system utilized in this area was clear-cutting with full-tree skidding in alternating cut-and-leave blocks on a two-pass harvest plan (Lane 1998).

Weyerhaeuser Canada Ltd. supervised the logging operation according to the Alberta Timber Harvesting Planning and Operation Ground Rules (1994) and the Weyerhaeuser Annual Operating Plan (Lane 1998).

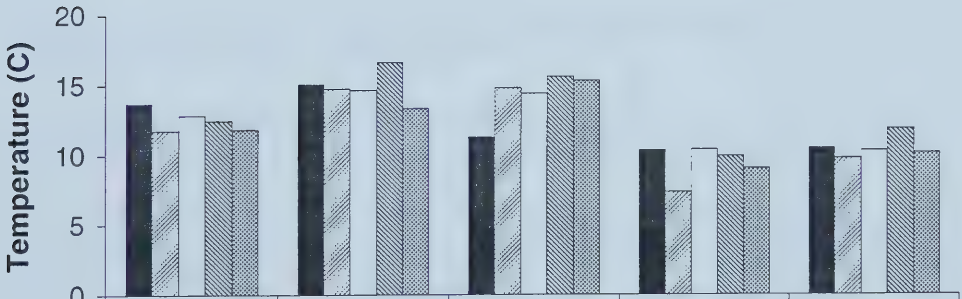
Full-tree skidding operations transported trees from stump to decking sites for de-limbing and cutting into shorter lengths (Weyerhaeuser 1996, Zasada and Tappeiner 1969). Skidding of trees from stumps to decking sites created a series of narrow trails through the forest. Repeated use of skid-trails resulted in removal of standing vegetation and increased soil exposure (Lane 1998). To prevent extensive soil compaction skidding equipment was fitted with large rubber tires, areas sensitive to compaction were restricted from harvest, and harvest operations were suspended during periods of extended precipitation (Weyerhaeuser 1996). Post-skidding operations included de-limbing, cutting and stacking of aspen logs along road allowances. Heavy slash accumulations were piled and burned, while lighter slash accumulations were spread over decking sites to preserve soil moisture, and prevent erosion (Weyerhaeuser 1996).

Construction of logging roads occurred in two phases. Pre-harvest road construction consisted of an excavation of organic soil layers and vegetation, and subsequent compaction of mineral soil layers to form a hardpan upon which flatbed trucks transported logs. Following harvest, the aforementioned roads were ripped and loaded with woody debris accumulated during de-limbing (Lane 1998), in an effort to discourage use of ripped logging roads by cattle.



	June	July	Aug	Sept	Apr-Sept
1995	74	89	103	10	329
1996	68	105	77	72	449
1997	128	114	47	52	407
1998	89	28	72	52	306
1999	42	94	47	9	298

Figure 1-1. Mean monthly precipitation at Shining Bank weather station (1995-1999).



	June	July	Aug	Sept	Apr-Sept
1995	13.7	15.1	11.3	10.4	10.5
1996	11.7	14.8	14.9	7.4	9.8
1997	12.8	14.7	14.5	10.4	10.4
1998	12.5	16.7	15.6	10.0	11.9
1999	11.8	13.4	15.4	9.1	10.2

Figure 1-2. Mean monthly temperature at Shining Bank weather station (1995 - 1999).

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2.0 Effects of Cattle and Wild Ungulate Foraging on Post-Harvest Regeneration of Trembling Aspen

2.1 Introduction

Trembling aspen (*Populus tremuloides*) is an important commodity in Alberta, and throughout western Canada's forest sector. Technological advances in wood-fiber processing have created a highly profitable aspen industry (Peterson and Peterson 1992). Trembling aspen and balsam poplar are now used to produce Oriented Strand Board (OSB), pulp, lumber, and numerous specialized products (Peterson and Peterson 1992).

Members of the *Populus* genus exhibit strong root suckering capacity that generally makes post-harvest management of aspen forests relatively easy versus other forest types (Navratil 1991). Vegetative reproduction in *Populus* species is induced by disruption of apical dominance and promoted by greater soil temperatures (Peterson and Peterson 1992). Full suckering in recently logged aspen stands requires a disruption of apical dominance; clear-cut logging should be the most effective method of harvest (Schier 1981). Many other factors can either promote or deter vigorous suckering in *Populus* species: soil properties (Maini and Horton 1966, 1964), pre-harvest stand and root characteristics (Kemperman 1978, Maini 1967, Horton and Maini 1964), and hormone regulation (Schier 1976, Steneker 1972, Farmer 1962). Ultimately, successful establishment of a healthy trembling aspen stand is dependent upon a diverse matrix of environmental parameters.

Recently, post-harvest surveys of some regenerating aspen stands have noted unsatisfactory tree stocking rates. Silvicultural prescriptions, site characteristics, and method of harvest are all potential inhibitors of aspen regeneration (Navratil 1991). In

this multiple-use landscape, the forest company is concerned that poor stand regeneration is a result of cattle trampling and foraging of aspen suckers.

Grazing of cut-blocks by cattle can negatively affect trembling aspen regeneration under some circumstances. Ungulate damage to trees usually occurs in one of three forms: consumption of leaves, browsing of shoots, and incidental trampling of stems. Repeated foraging by cattle can limit aspen stem heights to less than one meter (Krebill 1972), and reduce long-term stem survival (DeByle and Winokur 1985). Bailey et al. (1990) also report short-duration high-intensity cattle grazing as being detrimental to aspen regeneration. Cattle utilization of trembling aspen has the potential to reduce sucker growth, impeding stand regeneration.

Alberta's crown lands are managed with a mandate of multiple land-use, creating conflicts between livestock producers and timber producers regarding the impact of cattle on aspen regeneration. Livestock producers require a source of forage for their herds year round. Expansion of beef cattle production in Alberta has increased the use of aspen dominated southern boreal forests as forage resources via forest grazing leases. Without the availability and use of forest grazing leases forage supply requirements of livestock producers could not be met.

While cattle foraging has the potential to reduce aspen growth, cattle impacts depend upon grazing pressure and stocking rates (animal units per hectare per month) (Ratliff and Denton 1995, Jones 1983). Distribution and season of cattle grazing are also key issues to be addressed in regenerating forests (Ratliff and Denton 1995). Previous studies of cattle grazing in Alberta's aspen forests suggest that cattle have no significant

impact upon stand regeneration (Sundquist 1995, Wheeler and Willoughby 1993, Weatherhill and Keith 1969).

Foraging pressure in regenerating aspen stands is not due exclusively to domestic livestock. White tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), wapiti *(Cervus elaphus*), and moose (*Alces alces*) are all indigenous to Alberta's lower boreal forest. Woody forage species are generally utilized in greater proportions by wild ungulates, particularly moose than by cattle (Roy and Rangen 1997). Wild ungulates can impact forest regeneration to an equal or greater extent than cattle (Graham and Kingery 1990). Regeneration of aspen stands in Utah either failed or occurred at reduced stem densities in the presence of wild ungulate browsing (Bartos and Kay 2000). It is critical that wild and domestic ungulates both be considered potential sources of damage to regenerating aspen stands.

The purpose of this study is to assess the impacts of summer cattle grazing and year round wild ungulate browsing on regeneration of trembling aspen stands in a multiple-use landscape. The following null hypotheses were tested:

1) Wild ungulate foraging in the absence of cattle foraging does not significantly affect mean aspen stem height or mean aspen stem density in cut-blocks.

2) Absence of wild ungulates and cattle from cut-blocks does not significantly affect mean aspen stem height and mean aspen stem density.

3) 1-Year, 2-Year, and permanent deferrals of cattle foraging in cut-blocks do not significantly affect mean aspen stem height and mean aspen stem density within June-July (early season) or August-September (late season) grazing systems.

2.2 Methodology

During the summer of 1994, 900 hectares of the study area was harvested utilizing full-tree skidding. Subsequently, approximately 100 cow/calf pairs foraged these cut-blocks from 1995 until 1999. Six 50m x 100m permanent exclosures were constructed, three within cut-blocks designated for early season grazing (June-July cattle access) and three within cut-blocks designated for late season grazing (August-September cattle access). Suitable exclosure sites were randomly selected from among all sites that were moderately or well drained and level to gently sloping (<10°).

2.2.1 Experimental Design – Wild Ungulate Browsing

A study of wildlife browsing was undertaken utilizing four 100 m x 50 m permanent cattle exclosures, and four 15m x 15m permanent wild ungulate and cattle exclosures (Figure 2-2). The effects of wild ungulate browsing on aspen regeneration were isolated from the effects of cattle foraging by constructing four permanent wild ungulate exclosures using 2.5 m high page wire fences. Areas with 2.5 m fences excluded both cattle and wild ungulates, while those with 1.5 m fences excluded cattle but permitted wild ungulate access. The central fence did not restrict wild ungulate movements, allowing all four permanent cattle exclosures to be considered as one treatment (wild ungulate access, absence of cattle), regardless of their orientation with respect to early or late season cattle grazing.

A randomized complete block design was used for this study, with four blocks located across three cut-blocks. Sampling within each combination of replicate and treatment was performed in fifteen randomly located 2 m^2 permanent plots. Suitability of an area for permanent plots was determined by visual inspections of surface disturbance,

accumulation of coarse woody debris (≥4cm diameter) and drainage at time of plot establishment. Suitable areas for permanent plots had no standing water, light to moderate disturbance regimes and no accumulation of coarse woody debris.

2.2.2 Experimental Design – Cattle Grazing Treatments

In addition to the 50 m x 100 m permanent cattle exclosures, three other treatments were established to examine the effects of cattle foraging on aspen regeneration in cut-blocks. Adjacent to each permanent cattle exclosure two areas measuring 20m x 30m (600 m^2) were constructed using electric fences to create a 1-year deferral of cattle and 2-year deferral of cattle (Fig. 2-2). One 20 m x 30 m (600 m^2) unfenced area was delineated near each permanent cattle exclosure and designated for annual cattle grazing (Table 2-1.).

Table 2-1. Cattle access to grazing treatments in five-year study of grazing impacts upon aspen regeneration.

Grazing Treatment	Years of Deferral	1995	1996	1997	1998	1999
Annual Grazing	None	Grazed	Grazed	Grazed	Grazed	Grazed
1 Year Deferral	1	Deferred	Grazed	Grazed	Grazed	Grazed
2 Year Deferral	2	Deferred	Deferred	Grazed	Grazed	Grazed
Permanent Deferral	5	Deferred	Deferred	Deferred	Deferred	Deferred

A randomized complete block design was used for both early season grazing and late season grazing systems, with three blocks located in the early season grazing area and three blocks located in the late season grazing area. Sampling within each combination of replicate and treatment was performed in fifteen randomly located 2 m^2 permanent plots. Suitability of an area for permanent plots was determined by visual inspections of surface disturbance, accumulation of coarse woody debris (≥4cm diameter)

and drainage at time of plot establishment. Suitable areas for permanent plots had no standing water, light to moderate disturbance regimes and no accumulation of coarse woody debris.

2.2.3 Experimental Design – Forage Biomass

Vegetation biomass was measured during the 1998 and 1999 growing seasons within annual grazing, 1-year deferral of cattle, and 2-year deferral of cattle treatments. Six 1.5 m x 1.5 m x 1.5 m cages were erected inside each of these treatments at each experimental block in both early season and late season grazing systems. A 0.5 m x 1 m area inside of each cage was clipped of all live vegetation during late July to assess forage biomass at each year post-harvest. Subsequently, vegetation was sorted into four categories: aspen, balsam, grass, and forbs/shrubs then dried at 100°C for twenty four hours prior to being weighed. Trembling aspen and balsam poplar clippings represented accumulated growth, while forb, shrub and grass clippings represented current annual growth.

2.2.4 Measurements – Cattle and Wild Ungulate Foraging Treatments

Vegetation measurements were made at each permanent plot (15 per treatment x replicate combination) at three intervals during the growing season (late May, late July, and late September). Density measures for both trembling aspen and balsam poplar were made at each plot for each measurement period. Heights of the five tallest trembling aspen stems were also recorded for each permanent plot at each measurement date. Stem height was measured as the distance from root collar to base of shoot apex. Where less than five trembling aspen stems occurred, all trembling aspen stems present were first measured, and balsam poplar stems were then included to a sum of five stems per plot

wherever possible. Blended measurements of trembling aspen and balsam poplar are referenced hereafter as *Populus* height or *Populus* density.

2.2.5 Data Analysis – Wild Ungulate Browsing

The following model was used to analyze the effects of wild ungulate exclusion and cattle/wild ungulate exclusion on aspen stem height and stem density:

$$Y_{ij} = B_i + T_j + e_{ij}$$

Y = Height (cm) or Density (stems/ha)	B = Block
T = Grazing system treatment	e = Experimental error

This was accomplished by comparing treatments that excluded cattle and wild ungulates with treatments that excluded cattle but permitted wild ungulate access. Analysis of variance (ANOVA) was completed using SAS (SAS Institute, Inc. 1989) based upon the above model. Tukey's adjusted T-tests were then used to identify significant differences in stem height or stem density by treatment.

2.2.6 Data Analysis – Cattle Grazing Treatments

The following model was used to analyze the effects of cattle grazing on aspen stem height and stem density in both June-July and August-September grazing systems:

$$Y_{ij} = B_i + T_j + e_{ij}$$

Y = Height (cm) or Density (stems/ha)	B = Block
T = Grazing deferral treatment	e = Experimental error

Analysis of variance (ANOVA) was completed using SAS (SAS Institute, Inc. 1989) based upon the above model. Tukey's method of multiple comparisons among means was then used to identify treatments with significantly different stem height or stem density.

2.2.7 Data Analysis – Forage Biomass

The effects of cattle deferral treatment on average biomass of aspen, balsam, grass and forbs/shrubs during the 1998 and 1999 growing seasons was analyzed with the following model:

$$Y_{ij} = B_i + T_j + e_{ij}$$

Y = Forage biomass of a particular vegetation type (kg/ha) B = Block

T = Grazing deferral treatment e = Experimental error

Analysis of variance (ANOVA) was completed using SAS (SAS Institute, Inc. 1989) based upon the above model. Least significant difference (LSD) t-tests were then used to identify treatments with significantly different forage biomass for each vegetation type.

2.3 Results

2.3.1 Wild Ungulate Browsing

At five years post harvest, *Populus* stem height and density did not vary significantly between permanent wild ungulate/cattle exclosures and permanent cattle-only exclosures (Table 2-2). Similarly, trembling aspen stem height and density were not significantly different between the two treatments.

Table 2-2 *Populus* (trembling aspen and balsam poplar) and trembling aspen height and density relative to permanent exclusion of cattle and permanent exclusion of wild ungulates and cattle. Values with different letters that occur within the same column are significantly different ($p<0.05$).

Grazing Deferral Treatment	1999 mean *Populus* stem height (cm)	1999 mean *Populus* stem density (stems/ha)	1999 mean trembling aspen stem height (cm)	1999 mean trembling aspen density (stems/ha)
Perm. Deferral of Cattle	171 a	14400 a	144 a	12700 a
Perm Deferral of Wild Ungulates & Cattle	162 a	13500 a	171 a	12800 a

2.3.2 Early Season Cattle Grazing System

At five years post-harvest (1999), mean *Populus* stem height was greatest in those treatments that provided longer deferrals of cattle foraging (Table 2-3). Mean *Populus* stem height increased in all grazing treatments between 1995 and 1999 (Fig. 2-3), while mean *Populus* stem density decreased in all treatments during the same period (Fig. 2-4). Mean *Populus* stem density was also positively affected by longer deferrals of cattle grazing. Annual grazing by cattle was most detrimental to mean *Populus* height after five years (Table 2-3). However, in the absence of cattle grazing mean *Populus* height and density were significantly greater. In the early season grazing system (June-July), a two-year deferral or permanent deferral of cattle grazing significantly improved mean *Populus* height when compared to the annually grazed treatment.

Table 2-3 Mean *Populus* (trembling aspen and balsam poplar) and trembling aspen height and density relative to early season cattle grazing (ESG) at 5 years post harvest. Values with different letters that occur within the same column are significantly different ($p<0.05$).

Deferral of Cattle Grazing Treatment	1999 ESG mean *Populus* stem height (cm)	1999 ESG mean *Populus* stem density (stems/ha)	1999 ESG mean trembling aspen stem height (cm)	1999 ESG mean trembling aspen density (stems/ha)
Perm. Deferral	145 a	9800 a	127 a	9400 a
Annual Grazing	60 c	6000 b	60 c	6000 a
1-Year Deferral	84 bc	6400 b	83 bc	6300 a
2-Year Deferral	109 ab	8400 b	107 ab	7900 a

Mean aspen stem height increased in all treatments between 1995 and 1999 (Fig 2-5), while mean stem density decreased in all treatments during the same period (Fig. 2-6). Mean trembling aspen stem height was highest in the absence of cattle grazing and lowest in the annual cattle grazing treatment at five years post harvest (Table 2-3). Mean

aspen stem height in the permanent and 2-year deferral of cattle grazing was significantly greater than in areas grazed annually by cattle. Mean aspen stem density did not vary significantly among deferral treatments (Table 2-3).

2.3.3 Late Season Cattle Grazing System

There were no significant differences detected for mean *Populus* stem height or density among treatments in the late season (August-September) grazing system at five years post-harvest (Table 2-4). Mean *Populus* stem height increased in all deferral treatments between 1995 and 1999 (Fig.2-7), while *Populus* stem density decreased in all treatments during the same period (Fig. 2-8). Similarly, mean aspen stem height increased in all grazing treatments between 1995 and 1999 (Fig 2-9), while mean aspen stem density decreased in all treatments during the same period (Fig. 2-10). There were no significant differences in mean trembling aspen height or density among grazing treatments in the late season grazing system (Table 2-4).

Table 2-4 Mean *Populus* (trembling aspen and balsam poplar) and trembling aspen height and density relative to late season cattle grazing (LSG) at 5 years post-harvest. Values with different letters that occur within the same column are significantly different ($p<0.05$).

Deferral of Cattle Grazing Treatment	1999 LSG mean *Populus* stem height (cm)	1999 LSG *Populus* stem density (stems/ha)	1999 LSS mean aspen stem height (cm)	1999 LSG aspen stem density (stems/ha)
Perm. Deferral	189 a	14800 a	170 a	11000 a
Annual Grazing	149 a	8900 a	142 a	6100 a
1-Year Deferral	197 a	9400 a	185 a	9300 a
2-Year Deferral	181 a	12900 a	148 a	8500 a

2.3.4 Forage Biomass Production

Biomass of some forage types within the early season cattle grazing system varied by treatment (Table 2-5). Due to a random sampling effort there was very little production of balsam poplar noted within early season grazing treatments.

Table 2-5. Comparison of average biomass (kg/ha) 1998 – 1999 among four vegetation types and three grazing treatments within early season grazing system. Values with different letters within the same vegetation type are significantly different ($p<0.05$).

Cattle Grazing Deferral	Trembling Aspen Biomass	Balsam Poplar Biomass	Grass Biomass	Forb&Shrub Biomass	Total Biomass
None	300 b	1 a	790 a	1050 a	2180 a
1-Year	540 ab	0 a	800 a	750 ab	2080 a
2-Year	830 a	85 a	1360 a	720 b	3000 b

Total biomass production was significantly greater in the two-year deferral compared to the annual grazing treatment and one-year deferral treatment. Similarly, trembling aspen biomass was significantly greater in the two-year deferral than the annual grazing treatment. However, forb and shrub production was greatest within the annual grazing treatment and lowest in the two-year deferral, likely due to large quantities of clover (*Trifolium* spp.) on heavily grazed sites. Biomass of grass and balsam poplar did not vary by grazing treatment.

For August-September cattle grazing systems, biomass production varied by forage type and treatment (Table 2-6). Total biomass production in the one-year deferral was significantly higher than the two-year deferral. Similarly, average grass biomass in the one-year deferral was significantly greater than the two-year deferral. There were no

significant differences detected in average biomass among treatments for all other vegetation types.

Table 2-6. Comparison of average biomass (kg/ha) 1998 – 1999 among four vegetation types and three grazing treatments within late season grazing system. Values with different letters within the same vegeation type are significantly different ($p<0.05$).

Cattle Grazing Deferral	Trembling Aspen Biomass	Balsam Poplar Biomass	Grass Biomass	Forb&Shrub Biomass	Total Biomass
None	960 a	350 a	1130 ab	1210 a	3650 ab
1 year	920 a	660 a	1260 a	1080 a	3920 a
2 year	790 a	460 a	940 b	1010 a	3210 b

2.4 Discussion

Trembling aspen regeneration was examined in relation to four cattle grazing treatments in early season and late season grazing systems. Aspen regeneration was also examined in the presence and absence of wild ungulates. Mean *Populus* and trembling aspen stem height and density were monitored over a period of five years, allowing different treatments to be ranked in terms of successful aspen regeneration. Optimal cattle grazing treatments were identified with respect to facilitation of aspen regeneration and achievement of provincial establishment standards.

2.4.1 Wild Ungulate Browsing

No significant impact of wild ungulates on trembling aspen regeneration was detected in this study, suggesting that resident and transient wild ungulate populations within the area can be sustained without detriment to aspen regeneration. However, there was concern regarding the effect of exclosure fences on wild ungulate movements. Half hectare cattle exclosures used in this study were below the 0.4 ha minimum area

suggested for equitable deer distribution (Julander 1958) and the 4 ha minimum area suggested for equitable elk distribution inside and adjacent to cattle exclosures in grass/shrub communities (Gross and Knight 2000). However, incidental observations of wild ungulate beds and pellet groups within cattle exclusures indicated that fences had less influence on wild ungulate movement in regenerating forests.

In the presence of wild ungulates and absence of cattle, provincial establishment standards for a deciduous forest type were attainable. Mean aspen stem height and density did not differ between cattle-only exclosures and wild ungulate plus cattle exclosures. However, in areas having higher wild ungulate populations than this study area, cumulative impacts from cattle and wild ungulate foraging may impede aspen regeneration.

2.4.2 Cattle Foraging and Aspen Establishment Standards

In an effort to assure sustainable timber yields, Alberta's provincial government described minimum stand establishment standards for timber producers to meet by 3-5 years post harvest (Anonymous 2000). In deciduous cut-blocks of the Lower Foothills Subregion acceptable trees should be ≥ 3 years of age, alive, healthy, undamaged, and $\geq$ 80 centimeters in height at 3-5 years post-harvest. In addition, satisfactorily restocked areas will have 7000 acceptable deciduous trees per hectare with an average height of 140 centimeters. If harvested aspen stands fail to meet specified establishment standards the forest company could incur financial penalties.

Within the early season grazing system, trembling aspen regeneration was least successful in the presence of annual cattle grazing. Mean aspen stem density was below establishment standards within annual cattle grazing treatments in both early season and

late season grazing systems. Although the annual grazing treatment permitted foraging by wild ungulates and cattle, insignificant wild ungulate impacts indicate that cattle were likely responsible for failed aspen regeneration in the early season grazing system.

On average, no treatment in the early season grazing system produced mean aspen stem height that met establishment standards. However, aspen height standards were met in the permanent cattle deferral treatment at two of three sites. Conversely, mean aspen stem height at five years post harvest met establishment standards in all treatments within the late season grazing system.

Trembling aspen regeneration was most successful in those treatments that provided either a two-year or permanent deferral of cattle grazing. Regardless of treatment, late season grazing had a minimal impact on aspen regeneration while early season grazing impeded aspen regeneration. Unfortunately, experimental design and herd management requirements precluded statistical comparison of like treatments between early season and late season grazing systems.

Studies of cattle impacts on trembling aspen regeneration performed in Alberta's Aspen Parkland note greater utilization of trembling aspen by cattle late in the growing season (Fitzgerald and Bailey 1984). However, in the aforementioned study cattle were confined within pastures and consumed aspen only after herbaceous forage resources and preferred browse species were depleted. In this study area, early summer forage options appeared to be limited by delayed emergence of herbaceous vegetation, causing cattle to consume trembling aspen during June and July. Deferring grazing of aspen cut-blocks by cattle until August should permit successful aspen regeneration, as late season cattle grazing was compatible with forest regeneration.

2.4.3 Distribution of Cattle in Cut-Blocks

Uniform distribution of cattle in the early season grazing system was difficult to achieve. Although each experimental block in the early season grazing system met the same selection criteria, a lack of knowledge and/or consideration regarding preexisting cattle behavior resulted in uneven grazing pressure. Cattle spent a disproportionate amount of time in close proximity to one experimental block in the early season grazing system. Problems with grazing distribution resulted primarily from historically patterned cattle behavior, and were likely created by the spatial arrangement of road disturbances, petroleum exploration and drilling locations, seismic cut lines, and cattle salting locations. However, areas grazed in August-September were less impacted by spatial disturbances, which afforded more uniform grazing distribution.

Activities that impact cattle grazing patterns in forest landscapes must be considered more thoroughly. Cattle are known to frequent logging roads (Roath and Krueger 1982), but the effect of petroleum well sites and additional disturbances on cattle distribution are uncertain. Removal of cattle with preferences for particular habitats, or with small home ranges could also improve grazing distribution. Year to year, only 3% of individual cattle have substantially different home ranges (Howery et al. 1996). Status within herd, age of individual, and presence/absence of calf could also affect cattle distribution in cut-blocks.

Summer grazing of cut-blocks by cattle reduced the opportunity for timber producers to achieve adequate stand regeneration. Poor management of cattle impedes the regeneration of deciduous stands and threatens the sustainability of timber resources in Alberta's lower boreal forests.

2.4.3 Self Thinning of Trembling Aspen

Disruption of apical dominance via clear-cut harvesting initiated regeneration of trembling aspen within this stand. Moderate soil disturbance resulting from skidding and decking of felled trees reduced the area to an early seral stage in which vegetation competition was abundant. Intra-specific competition and inter-specific competition were evident, as individual plants competed for finite growing space and nutrients.

During the first two years post-harvest, aspen stem density declined across all treatments by approximately 100%. Rates of stem density reduction were comparable in the presence and absence of cattle, suggesting a natural thinning process due to intra-specific competition. Self-thinning is a key mechanism in many plant communities (Westoby 1984). Actively growing plant populations consistently approach and then follow a thinning pattern of approximately –3/2; referred to as the '–3/2 power law' (Yoda et al. 1963). Following the '–3/2 power law', healthy plant populations increase their total yield faster than density decreases; reduced intra-specific competition (lower density) produces larger individuals (greater mean weight) in a population. This pattern generally continues until individuals in a population cannot grow any larger under prevailing conditions, at which time any continued growth is expected to be balanced by the death of another individual in the population (Lonsdale & Watkinson 1982).

Self-thinning is known to occur in trembling aspen stands (Jones 1975, Graham et al. 1963); stand density decreases as less healthy individuals are removed from the population. This principle was evidenced by greater incremental increases in mean aspen stem height during all growth periods subsequent to 1995-1996. Regardless of grazing

treatment, trembling aspen showed the poorest growth rates during the 1995-1996 interval, when intra-specific competition was greatest.

2.4.4 Inter-specific Vegetation Competition

Vegetative reproduction makes trembling aspen and balsam poplar better suited to inter-specific competition than merchantable tree species grown from seed or seedling. Parent root systems of trembling aspen provide emergent suckers with energy until new shoots and leaves are established (Schier 1981). However, marsh reedgrass (*Calamagrostis canadensis*) impedes the growth of young aspen by lowering soil temperatures (Landhausser and Lieffers 1998). Cooler soil temperatures, resulting from marsh reedgrass insulation may have slowed aspen growth in some late season grazing treatments where mean aspen stem height was numerically greatest in the one-year deferral treatment at five years post harvest. Unfortunately, vegetation biomass measurements included only current year growth for grass and forb species, and thus did not indicate the amount of soil-insulating decadent vegetation present.

Within the late season grazing system palatability of marsh reedgrass may have declined before cattle were permitted to graze these areas. Permanent and two-year deferrals of cattle grazing could compound the problem of soil insulation by decadent grass, reducing aspen growth relative to a one-year deferral of cattle grazing. Permanent deferral of cattle grazing could result in consistently lower soil temperatures, causing aspen stem growth in this treatment to be reduced relative to stem growth in annual, one-year deferral, and two-year deferral treatments. In the long term, the most productive treatment within the late season grazing system could be that which permitted cattle foraging in all but the first year post-harvest.

Inter-specific competition among vegetation species was likely greater in the absence of cattle foraging. Light to moderate grazing by cattle could promote forest regeneration by reducing inter-specific competition. This could be particularly important in boreal environments where lower soil temperatures can limit aspen stem growth. The role of inter-specific vegetation in limiting seedling growth has been documented in coniferous forests (McLean et al. 1986, Clark and McLean 1975). All grazing systems reduce vegetation biomass. Cattle grazing could benefit aspen growth where vegetation consumed by livestock competes with aspen suckers for nutrients and resources. Grazing can also reduce seed production and propagation of competitive plant species (Clark and McLean 1979). Competition control can be particularly important on nutrient rich sites where high levels of competing vegetation can occur (Shelton and Murphy 1994). Providing micro-sites free of competition for young trees is a key principle of manual site preparation following stand harvest, a function that could be fulfilled by cattle grazing.

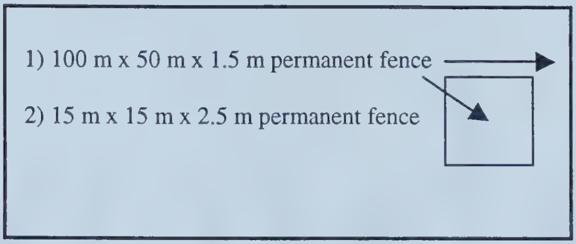
2.5 Conclusions

Wild ungulate foraging did not affect trembling aspen regeneration in the absence of cattle grazing. In the presence of cattle foraging wild ungulates had no additional impact on aspen regeneration.

Annual June-July grazing of cut-blocks by cattle in the first five years post-harvest severely impeded trembling aspen regeneration. Deferral of June-July grazing in the first year post-harvest was not successful in reducing the impacts of cattle grazing on aspen regeneration. Deferral of June-July grazing in the first two years post harvest markedly improved aspen regeneration relative to annually grazed areas. Among June-July deferral treatments, absence of cattle during the first five years post harvest

presented the best option for promoting aspen regeneration. However, absence of cattle foraging in the early season grazing system did not assure successful aspen regeneration relative to provincial forest establishment standards.

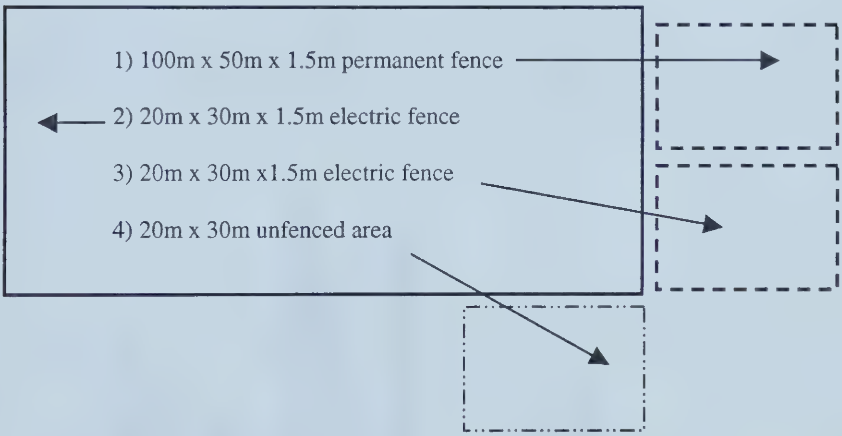
In Alberta, a multiple resource mandate established by the provincial government precludes the elimination of forest grazing leases, thus cattle grazing of regenerating aspen forests will persist. Grazing of cut-blocks by cattle during August-September did not impede trembling aspen regeneration, regardless of deferral treatment. Elimination of June-July cattle grazing during each growing season following stand harvest facilitated the establishment of a new aspen stand. Timing of cattle access to cut-blocks was a determinant of successful trembling aspen regeneration, highlighting the importance of proper livestock management in assuring successful stand regeneration in multiple-use landscapes. Livestock managers can better promote regeneration of trembling aspen by striving for equitable utilization of forage resources by cattle.



1) Annual Wild Ungulate Access, Absence of Cattle

2) Absence of Wild Ungulates and Cattle

Figure 2-1. Annotated diagram of typical experimental design for 1 block of wild ungulate study.



1) Absence of Cattle

2) 1-Year Deferral of Cattle Grazing

3) 2-Year Deferral of Cattle Grazing

4) Annual Cattle Grazing

Figure 2-2. Annotated diagram of typical experimental design for 1 block of cattle foraging study. Design applies to both June-July and August-September systems.

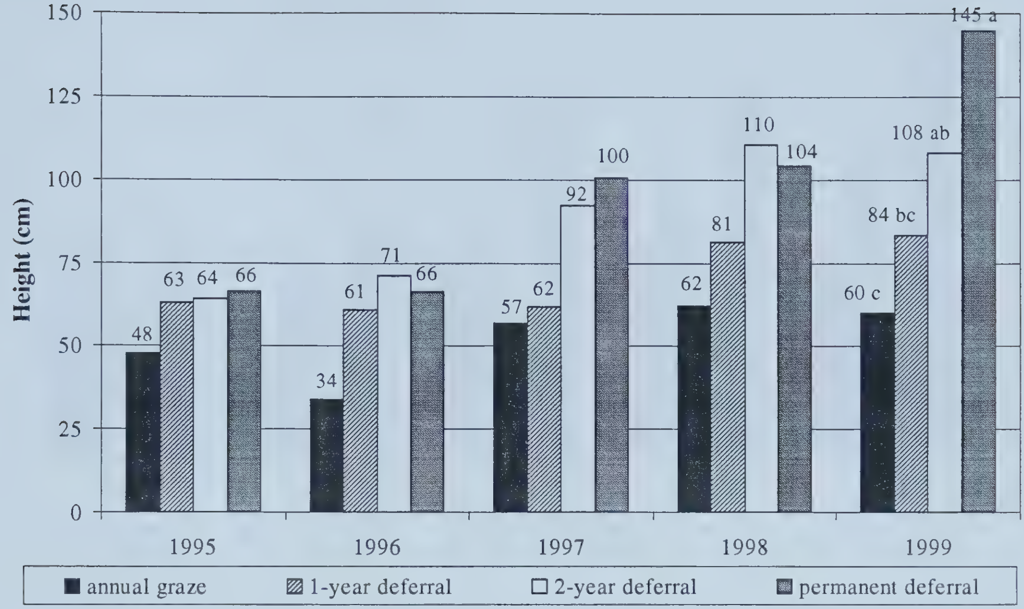


Figure 2-3. Comparison of mean *Populus* (trembling aspen and balsam poplar) height among cattle deferral treatments in the early season grazing system (June-July). In 1999, data points with different letters are significantly different (p<0.05).

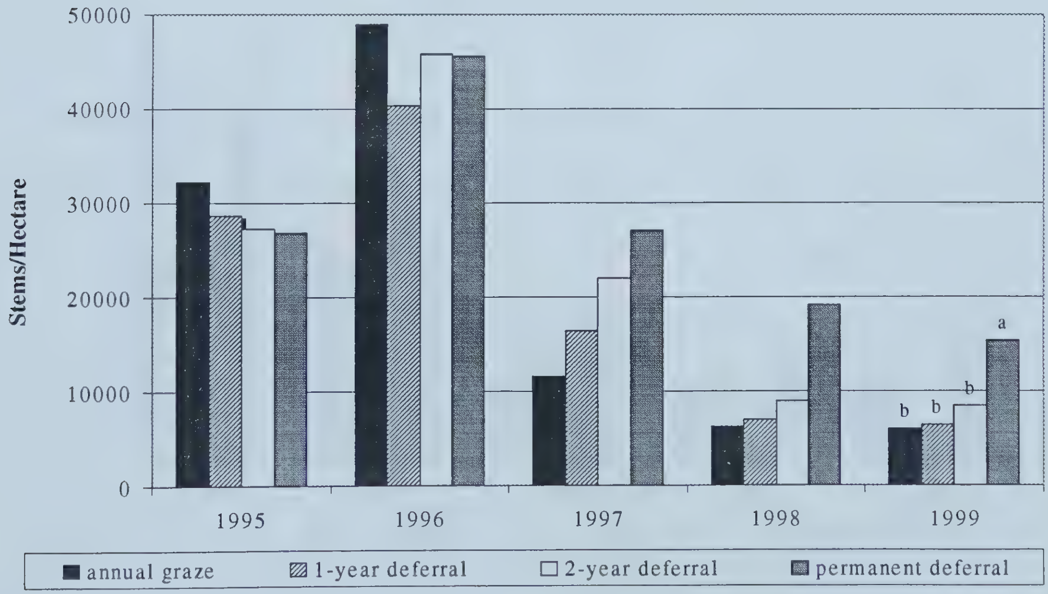


Figure 2-4. Comparison of mean *Populus* (trembling aspen and balsam poplar) density among cattle deferral treatments in the early season grazing system (June-July). In 1999, data points with different letters are significantly different (p<0.05).

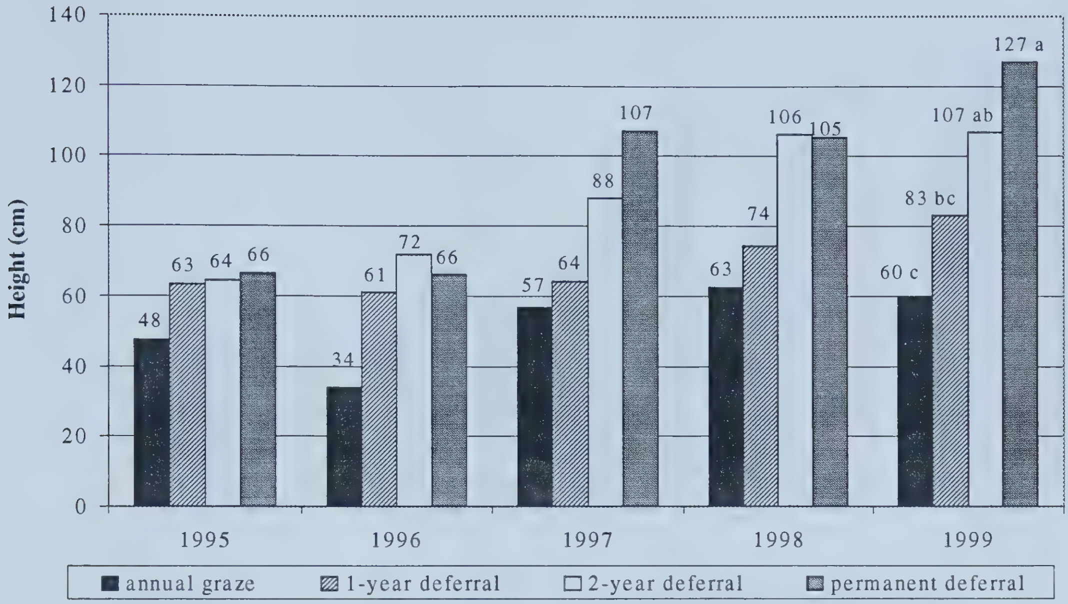


Figure 2-5. Comparison of mean trembling aspen height among cattle deferral treatments in the early seaso grazing system (June-July). In 1999, data points with different letters are significantly different (p<0.05).

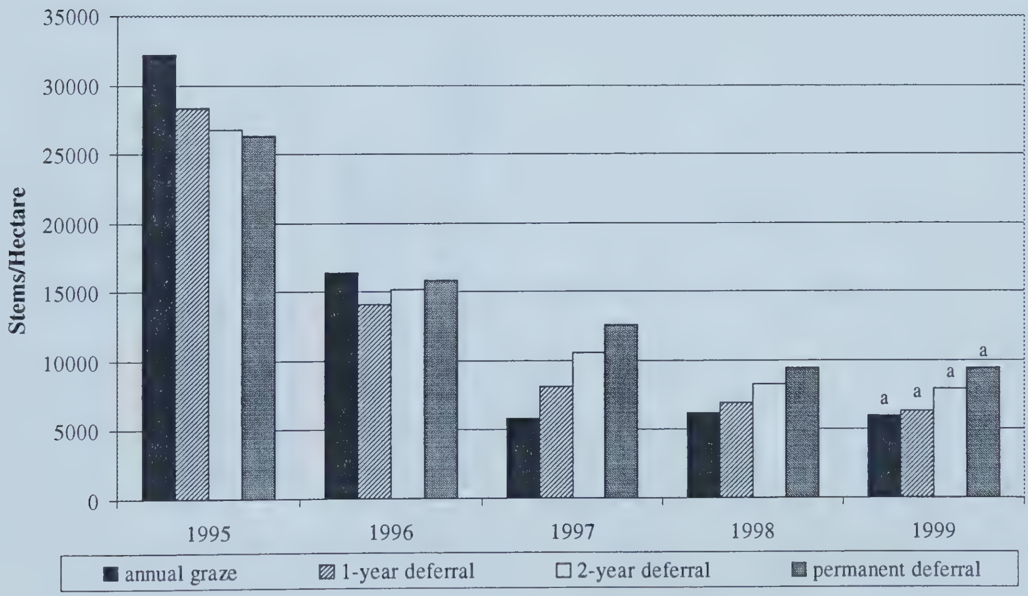


Figure 2-6. Comparison of mean trembling aspen density among cattle deferral treatments in the early season grazing system (June-July). No significant differences at 5 years post-harvest.

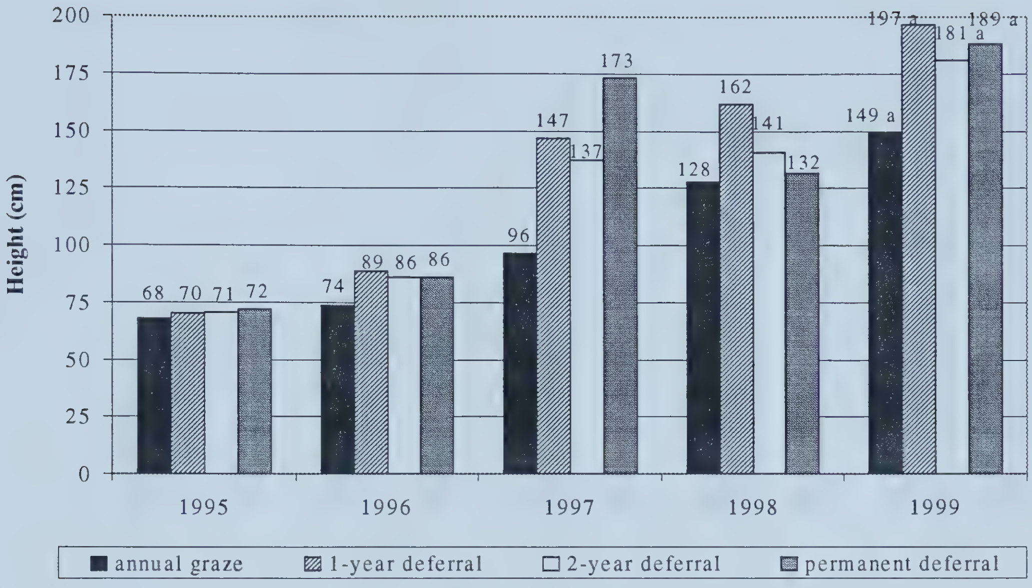


Figure 2-7. Comparison of mean *Populus* (trembling aspen and balsam poplar) height among cattle deferral treatments in the late season grazing system (August-September). No significant differences at 5 years post-harvest.

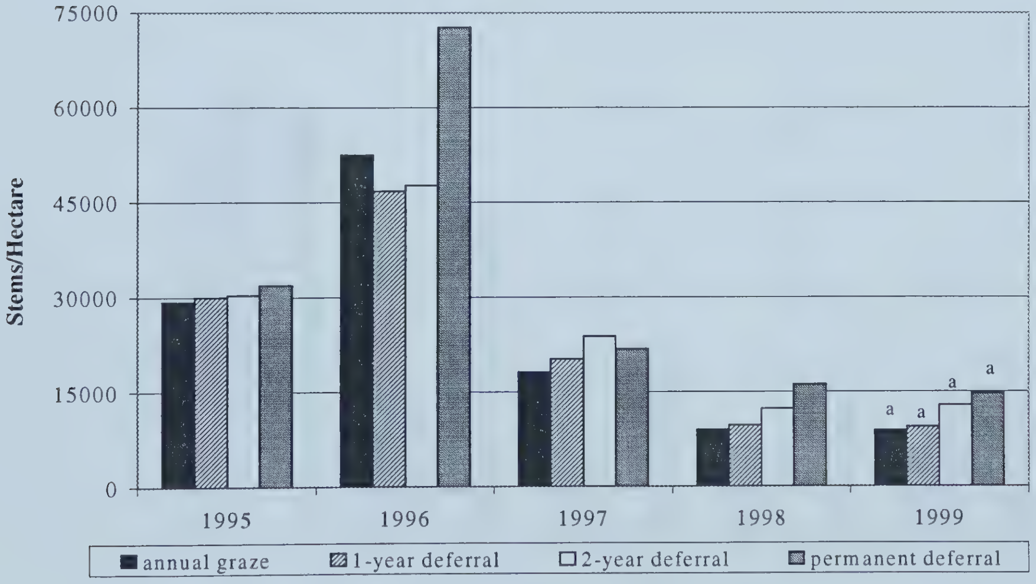


Figure 2-8. Comparison of mean *Populus* (trembling aspen and balsam poplar) density among cattle deferral treatments in the late season grazing system (August-September. No significant differences at 5 years post harvest.

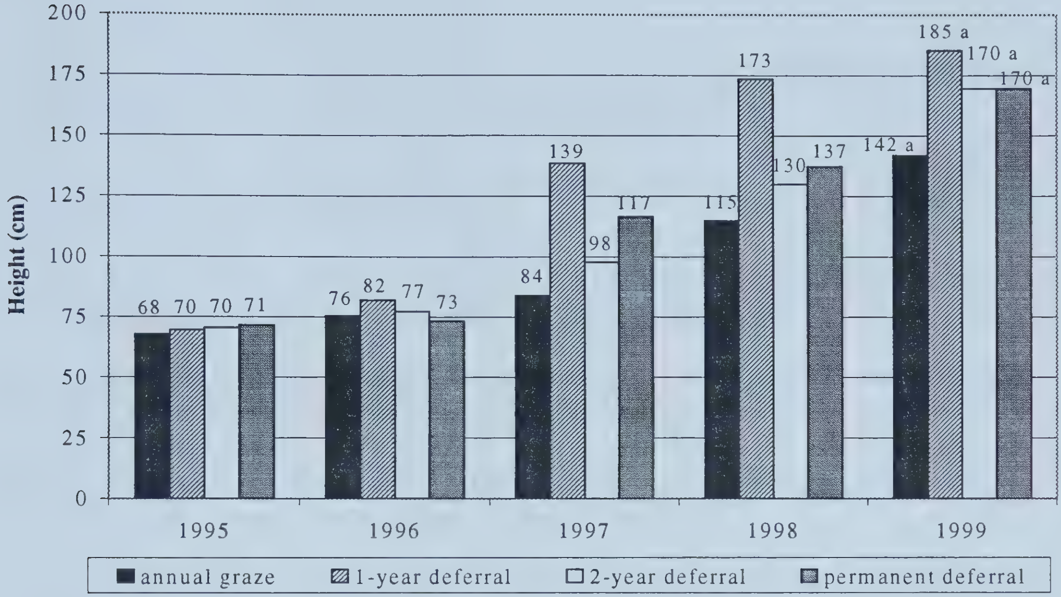


Figure 2-9. Comparison of mean aspen height among cattle deferral treatments in the late season grazing system (August-September). No significant differences at 5 years post harvest.

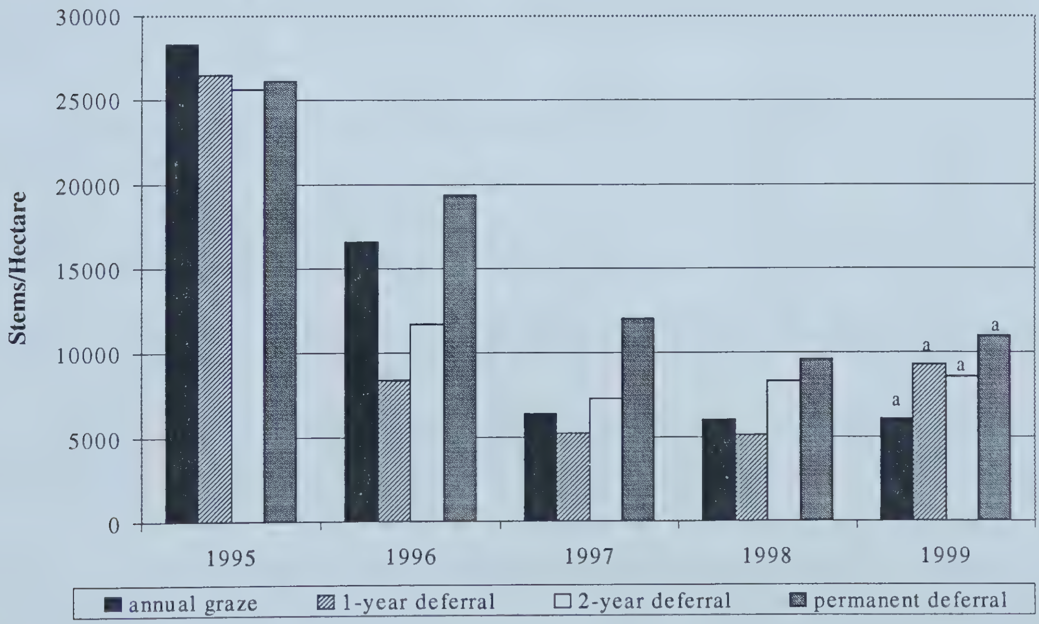


Figure 2-10. Comparison of mean aspen density among cattle deferral treatments in the late season grazing system (August-September). No significant differences at 5 years post harvest.

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3.0 Effect of Summer Cattle-Grazing on Aspen Stem Injury, Mortality and Growth

3.1 Introduction

Trembling aspen (*Populus tremuloides*) is an important commodity in Alberta, and throughout western Canada's forest sector. Technological advances in wood-fiber processing have created a highly profitable aspen industry (Peterson and Peterson 1992). Trembling aspen and balsam poplar (*Populus balsamifera*) are now used to produce Oriented Strand Board (OSB), pulp, lumber, and many specialized products (Peterson and Peterson 1992).

Members of the *Populus* genus exhibit a strong root suckering capacity that generally makes post-harvest management of aspen forests relatively easy versus other forest types (Navratil 1991). Vegetative reproduction in *Populus* species is induced by disruption of apical dominance, and promoted by greater soil temperatures (Peterson and Peterson 1992). Full suckering in recently logged aspen stands requires a disruption of apical dominance; clear-cut logging should be the most effective method of harvest (Schier 1981). Many other factors can either promote or deter vigorous suckering in *Populus* species: soil properties (Maini and Horton 1966, 1964), pre-harvest stand and root characteristics (Kemperman 1978, Maini 1967, Horton and Maini 1964), and hormone regulation (Schier 1976, Steneker 1972, Farmer 1962). Ultimately, successful establishment of a healthy trembling aspen stand is dependent upon a diverse matrix of environmental parameters.

Recently, post-harvest surveys of some trembling aspen stands have noted unsatisfactory tree stocking rates. Silvicultural prescription, site characteristics, and

method of harvest are all potential inhibitors of aspen regeneration (Navratil 1991). In this multiple-use landscape, the forest company is concerned that poor stand regeneration is a result of cattle trampling and foraging of aspen suckers.

Grazing of cut-blocks by cattle can negatively affect trembling aspen regeneration under some circumstances. Ungulate damage of trees usually occurs in one of three forms: consumption of leaves, browsing of shoots, and incidental trampling of stems. Repeated foraging by cattle can limit aspen stem heights to less than one meter (Krebill 1972), and reduce long-term stem survival (DeByle and Winokur 1985). Bailey et al. (1990) also report short-duration high-intensity cattle grazing as being detrimental to aspen regeneration. Cattle utilization of trembling aspen has the potential to reduce sucker growth, impeding stand regeneration.

Alberta's crown lands are managed with a mandate of multiple land-use, creating conflicts between livestock producers and timber producers regarding the impact of cattle on aspen regeneration. Livestock producers require a source of forage for their herds year round. Expansion of beef cattle production in Alberta has increased the use of aspen dominated southern boreal forests as forage resources via forest grazing leases. Without the availability and use of forest grazing leases forage supply requirements of livestock producers could not be met.

While cattle foraging has the potential to reduce aspen growth, cattle impacts depend upon grazing pressure and stocking rates (animal units per hectare per month) (Ratliff and Denton 1995, Jones 1983). Distribution and season of cattle grazing are also key issues to be addressed in regenerating forests (Ratliff and Denton 1995). Previous studies of cattle grazing in Alberta's aspen forests suggest that cattle have no significant

impact upon stand regeneration (Sundquist 1995, Wheeler and Willoughby 1993, Weatherhill and Keith 1969). However, recent studies suggest early season grazing of cut-blocks by cattle can negatively affect aspen regeneration (Chapter 2, Lane 1998, Leoppky unpublished data).

The purpose of this study is to assess the impacts of monthly deferrals of cattle grazing on growth, incidence of wounding and mortality rate of trembling aspen in a multiple-use landscape. This study will aid resource managers in identifying the month(s) during which cattle damage to trembling aspen occurs most frequently. The following null hypothesis was tested:

1) June, July, and June-July deferrals of cattle access to cut-blocks will not significantly affect growth of trembling aspen, incidence of aspen stem wounding, or incidence of aspen stem mortality relative to continuous annual June-July cattle grazing.

3.2 Methodology

3.2.1 Experimental Design

During the summer of 1994, six cut-blocks were harvested utilizing full-tree skidding. Subsequently, approximately 100 cow/calf pairs foraged three of these cut-blocks during June-July of 1995, 1996, and 1997. In May of 1998, six blocks of four 20 m x 30 m plots were established within June-July grazed cut-blocks using 2 m fence posts and 3-strand barbed wire. Four treatments were randomly assigned to plots within each block (Table 3-1).

Table 3-1. Summary of deferral treatments and duration of cattle grazing access.

Cattle Grazing Treatment	Duration of Grazing (mo.)
June-July	2.0
June only	1.0
July only	1.0
No grazing	0.0

As wild ungulate foraging did not impact aspen regeneration in this area, this study addressed only the effects of cattle foraging. Replicates were randomly located within cut-blocks grazed during June-July by cattle. Replicate locations met the following criteria: moderate to well drained, moderate to good trembling aspen regeneration after three years of cattle foraging, absence of slash piles, and absence of severe physical disturbances during forest harvest.

3.2.2 Measurements – Grazing Deferrals

Within each deferral treatment, five 20 m x 2 m parallel transects were established. All stems present within each transect before June 1st of 1998 were individually numbered and tagged. During the summers of 1998 and 1999, height and basal diameter measurements were recorded for each individually tagged stem at three intervals (Table 3-2).

Table 3-2. Schedule of measurement intervals for all dependent variables.

Dependent Variable	May 28-30 1998, 1999	July 4-6 1998, 1999	August 7-9 1998, 1999
Aspen Height	Yes	Yes	Yes
Injury	Yes	Yes	Yes
Mortality	Yes	Yes	Yes
Aspen Density	Yes	No	Yes

In addition, each stem was classified at each measurement date as follows: 1. Damaged, 2. Not Damaged, 3. Dead. Where possible, source of stem mortality was identified. It was assumed that stem death noted during one measurement period was associated with stem damage (if any) during the immediately preceding measurement period of the same growing season. Thus if a stem was foraged at the July measurement period and dead at the August measurement period, foraging was considered the cause of death.

Aspen stem density was also monitored within the five transects of each deferral treatment throughout the study. Density was assessed by a visual count of aspen stems within each transect in May and August of both 1998 and 1999. Visual surveys accounted for all tagged stems that remained alive at the time of a count, plus all suckers newly initiated between count intervals.

3.2.3 Data Analysis – Grazing Deferrals

The following model was used to analyze the effect of deferral treatment on change in stem height, stem density, and total stem length. Stem characteristic data was analyzed using an Analysis of Variance (ANOVA) procedure along with Tukey's method of multiple comparisons among means using SAS (SAS Institute, Inc. 1989).

$$Y_{ij} = B_i + T_j + e_{ij}$$

Where: Y = Dependent variable B = Block

T = Grazing deferral treatment e = Experimental error

Stem mortality and injury data was analyzed using a MIXED procedure along with Tukey's test of least squared means because injury and mortality rates were represented as proportions, and variances among treatments were heterogeneous. Aspen

mortality is the aggregate of aspen mortality following stem injury and aspen mortality without stem injury. Further, paired t-tests were used to analyze the effect of yearly variation on wounding rates within each grazing treatment.

The following formula was then used to determine whether month of grazing or duration of grazing had a greater impact on aspen stem wounding and/or mortality:

June = N   July = L   JuneJuly = NL

Effect of month = N – L

Effect of duration = NL – (N + L)/2

Comparison of Month and Duration = 3N/2 – L/2 - NL

3.3 Results

3.3.1 Duration of Grazing, Trembling Aspen Growth and Damage Levels

Cattle deferral treatments had various impacts on aspen stem density after two years of application (Table 3-3). Absence of cattle and June-July grazing by cattle (Duration of Grazing = 2 months) had dramatically different impacts on change in aspen stem density. Treatments that permitted cattle access for one month (either June or July) partially or fully ameliorated the negative impacts of cattle on aspen regeneration.

Table 3-3. Selected trembling aspen stem characteristics after 3 years of continuous June-July cattle grazing and a subsequent two years of applied deferral treatments. Treatments with different letters are significantly different ($p<0.05$).

Grazing Treatment	Stem Height (cm)	Change in Stem Height (cm)	Total Stem Length (cm)	1998-1999 Change in Stem Density (#/ha)
No Grazing	99 a	+33.5 a	7503 a	+558 a
June-July Grazed	82 a	+2.6 c	2647 b	-658 b
June Grazed	80 a	+11.8 b	5114 ab	-150 ab
July Grazed	88 a	+19.4 b	7070 a	+67 ab

3.3.2 Stem Characteristics

After three years of June-July cattle grazing (1995-1997), absence of cattle grazing during 1998 and 1999 induced the greatest increase in aspen stem height and stem density, and the greatest total stem length (Table 3-3). Conversely, two additional years of June-July cattle grazing (1998-1999) induced a minimal change in stem height, markedly reduced stem density, and resulted in the lowest total stem length. June grazed and July grazed treatments showed significantly lower gains in aspen stem height compared to the ungrazed treatment (Fig. 3-2). Aspen stems in the ungrazed treatment experienced height gains 1200% greater than stems in the June-July grazed treatment, and 300% greater than stems in the June grazed treatment.

Two years of cattle deferral treatments had a significant impact on total aspen stem length (p=0.042). Differences in total stem length were insignificant between ungrazed and July grazed treatments (Fig. 3-3). The June-July grazed treatment exhibited a significantly lower total stem length after two years, than ungrazed and July grazed treatments.

Change in aspen stem density varied significantly by deferral treatment (p=0.026). Absence of cattle grazing resulted in the net recruitment of 558 stems per hectare between May 1998 and August 1999, while June-July cattle grazing caused a net loss of 658 stems per hectare during the same period (Fig. 3-4). Treatments that permitted cattle grazing during either June or July produced changes in stem density that were not statistically different from the ungrazed treatment.

3.3.3 Stem Wounding and Mortality

Mortality ($p<0.001$) and wounding ($p<0.001$) of trembling aspen stems varied significantly by deferral treatment after two years of application. Duration of cattle access had significant impacts on aspen stem wounding and mortality rates (Table 3-4). Absence of cattle produced the lowest aspen wounding and mortality rates. Areas grazed during July showed an equally low incidence of aspen stem mortality. In contrast, two additional years of June-July grazing (1998 and 1999) resulted in mortality for 31% of aspen stems. The mortality rate within June-July grazed treatments was 60% higher than June-grazed treatments, ~ 200% higher than ungrazed treatments, and nearly 300% higher than July grazed treatments (Fig. 3-5).

June-July cattle grazing produced the greatest incidence of stem wounding and mortality. June grazing resulted in significantly higher aspen stem wounding and mortality than July grazing. Month of cattle grazing had a more significant impact on the incidence of aspen stem wounding than did duration of cattle grazing.

Table 3-4. Trembling aspen stem wounding and mortality after 3 years of continuous June-July cattle grazing and a subsequent two years of applied grazing treatments. Treatments with different letters are significantly different ($p<0.05$)

Grazing Treatment	Aspen Stem Mortality (%)	Stem Mortality following Injury (%)	Stem Mortality without Injury (%)	Rate of Stem Injury (%)
No Grazing	13.2 c	12.7 b	13.2 b	11.7 c
June-July Grazed	30.7 a	27.5 a	35.0 a	65.0 a
June Grazed	18.7 b	12.3 b	32.5 a	68.3 a
July Grazed	11.8 c	17.8 ab	10.3 b	20.5 b

Among observed physical causes of mortality, foraging was responsible for the greatest proportion of stem death, followed by trampling and then disease (Fig. 3-6).

Approximately 60% of stem mortality was not associated with a physical injury; thus cause of death for those stems was categorized as unknown.

The percentage of trees that died following a grazing related injury (trampling, browsing, or leaf stripping) varied significantly by deferral treatment ($p=0.032$). Mortality rate was highest in the June-July grazed treatment (27.5%) and significantly lower in the June grazed and ungrazed treatments (Fig-3.5). Mortality of aspen stems following cattle related injury was not significantly different between June-July grazed and July grazed treatments. Mortality rate of aspen stems with no physical sign of injury also varied significantly by deferral treatment ($p=0.002$) (Table 3-4, Fig. 3-5). Mortality was lowest in ungrazed and July grazed treatments and highest in June grazed and June-July grazed treatments.

Absence of grazing and July grazing induced the lowest stem injury rates, while June grazing and June-July grazing induced the highest stem injury rates (Table 3-4, Fig. 3-5). Aspen stems within June grazed treatments and June-July grazed treatments were three times more likely to incur cattle damage than aspen stems in the July grazed treatment, and six times more likely than stems in the ungrazed treatment (Fig. 3-5). For all deferral treatments, incidence of wounding was significantly higher ($p<0.001$) during 1999 than 1998 (Fig. 3-7).

3.4 Discussion

Summer grazing of cut-blocks by cattle can affect aspen regeneration. Duration and timing of cattle access to cut-blocks affects the magnitude of impacts on aspen stem characteristics, wounding and mortality. Absence of cattle in cut-blocks was most closely associated with successful regeneration of a trembling aspen stand. Selection and

utilization of current-year aspen shoots and leaves by cattle impeded aspen stem growth and regeneration of a healthy sucker stand.

Utilization of aspen stems early in the growing season can render plants incapable of restoring the carbohydrate reserves drawn down during initiation of new growth (Schier 1976), thereby inhibiting stem growth during that growing season. Absence of cattle grazing was most beneficial to aspen growth, while two months of continuous cattle access was most detrimental to trembling aspen regeneration. A 50% reduction in duration of cattle access provided significantly better conditions for aspen regeneration than continuous June-July grazing. However, a single month of cattle access resulted in dramatically lower stem height gains and greater incidence of stem wounding than a complete absence of cattle.

Cattle deferral treatments that provided equal durations of grazing did not produce equal aspen wounding and mortality rates, suggesting differential cattle utilization of trembling aspen in June and July. June grazing induced significantly higher aspen wounding and mortality rates than July grazing; cattle made greater use of trembling aspen forage resources during June. Forage growth cycles are determined by a combination of photoperiod, soil temperature and plant hormones; herbage growth cycles begin in mid-May in prairie and aspen parkland communities (Irving 1992). However, initiation of herbaceous growth in boreal environments would occur later in the year due to the cooler climate, thus biomass of available herbage may be insufficient to support cattle grazing in the Lower Boreal Cordilleran eco-region during June. Subsequently, cattle could deplete herbage resources quickly and be forced to utilize alternate forage resources. Tender trembling aspen shoots and leaves could provide a viable alternative to

herbaceous forage early in the growing season because of expected high protein and moisture contents. Deferral of cattle grazing in forested landscapes until July could offset slower forage growth cycles, allowing trembling aspen stems to avoid selection by cattle early in the growing season.

Variation in aspen stem mortality and wounding rates by deferral treatment further emphasized that cattle impacts on trembling aspen regeneration were a function of livestock management. As suggested by Bailey and Arthur (1985), cattle showed a distinct preference for aspen shoots and leaves early in the growing season. However, significantly lower stem injury and mortality rates within July grazed treatments indicated that cattle preferences or trembling aspen palatability changed throughout the growing season. Prevention of aspen sucker wounding has critical management implications because provincial forest establishment standards dictate that trees included in regeneration surveys be undamaged (Anonymous 2000).

Aspen mortality rate within the ungrazed treatment (13.2% over 2 years) reflected a natural thinning rate for young aspen stands. A reduction of up to 80% in number of suckers per hectare is not uncommon from year 1 to year 5 (Peterson and Peterson 1992). Aspen mortality in June-July grazing treatment was approximately double annual thinning rates during the fourth and fifth years post-harvest, based upon stem mortality in the ungrazed treatments. Bailey and Arthur (1985) found that high-intensity early summer grazing by cattle resulted in the highest aspen mortality rates (58%). While June grazing caused a significant reduction in aspen mortality versus continuous June-July grazing in this study, mortality remained higher than would be expected by natural

thinning. However, aspen mortality within the July grazed treatment was comparable to expected natural thinning rates.

Comparison of dead stems without visible cattle induced wounds among treatments showed two distinct levels of mortality. Aspen mortality was approximately 35% within June grazed and June-July grazed treatments, but just 12% in July grazed and ungrazed treatments. A reduction in duration of grazing did not assure a similar reduction in aspen mortality for stems without visible cattle induced wounds. Aspen stems in the June grazed treatment were three times more likely to die compared to stems in the July grazed treatment. Stage of plant development and month of cattle access appear to play a significant role in determining aspen sucker mortality.

In this study, a majority of aspen stem mortality could not be associated with an observable stem injury. High mortality among stems without physical injuries was thought to be associated with soil compaction, reduced root oxygen and subsurface severing of suckers from parental roots. Seventy percent of aspen suckers arise from roots within eight centimeters of the soil surface, and 92% from within 12 centimeters of the soil surface (Schier and Campbell 1978). In addition, 93% of suckers originate from roots less than three centimeters in diameter. Aspen roots could be susceptible to damage because of their small diameters and their proximity to the soil surface.

Skidding traffic can reduce aspen suckering by injuring shallow lateral parent roots and compacting soil (Shepperd 1993). Cattle can cause significant upward and downward movement of soils, particularly under moist soil conditions (Betteridge et al 1999). Soil compaction can increase soil bulk density and reduce penetration of soil by nitrogen and water (Ferrero 1991, Bezekorowajnyj et al 1993). Repeated compaction of

soil can negatively affect root development. Cattle and harvest equipment could have similar impacts, compacting soils during early summer, causing greater stem mortality in June grazed treatments. Vegetation cover increased and soil moisture decreased throughout the growing season; rendering soils less susceptible to compaction and protecting aspen roots in the July grazed treatment from cattle damage.

3.5 Conclusions

Initiation of new aspen suckers was apparent in ungrazed and July grazed treatments. June and June-July cattle grazing resulted in greater reductions in aspen stem density than would be expected in the absence of June grazing. However, a fifty-percent decrease in duration of cattle access improved aspen stem growth, total stem length, and stem density after two years. Livestock grazing was most detrimental to aspen suckers during June. Continuous June-July grazing exacerbated the negative impacts of livestock grazing on aspen regeneration. Deferral of cattle access until July dramatically improved aspen regeneration; it was thought that alternate forage was readily available by July, reducing the need for cattle to consume aspen stem parts.

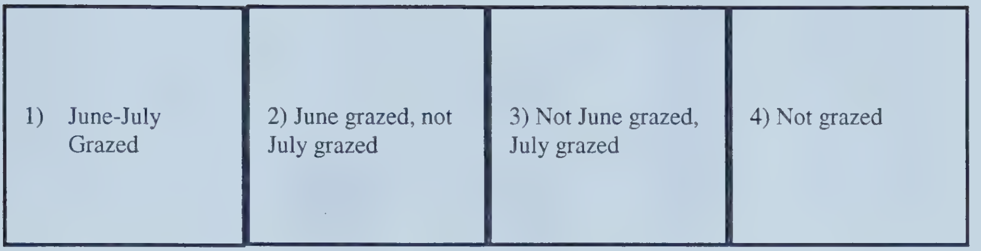


Figure 3-1. Sample layout of four treatments within one experimental block.

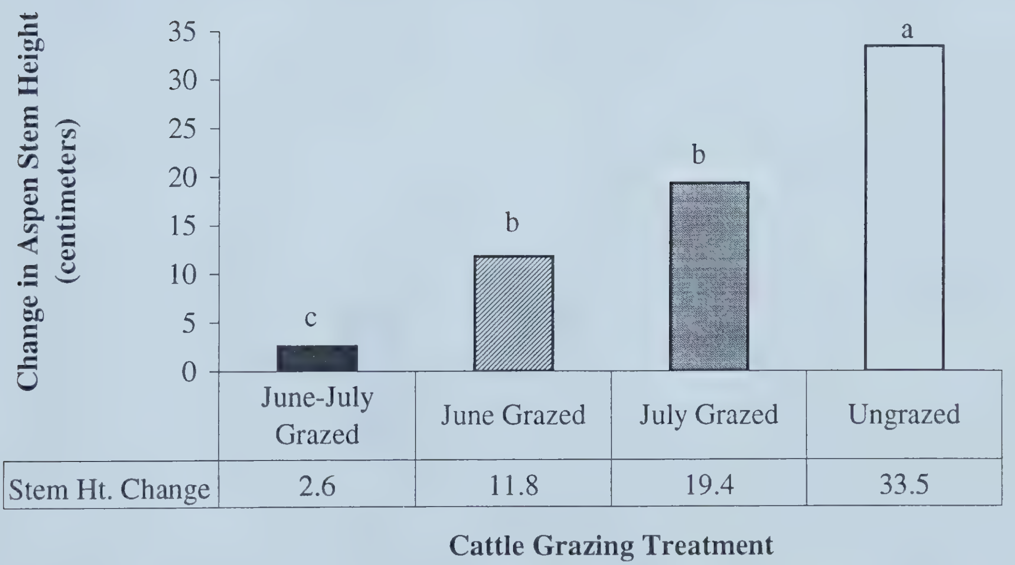


Figure 3-2. Effect of four grazing treatments on change in aspen stem height (cm) after two years of application. Columns with different letters are significantly different ($p<0.05$).

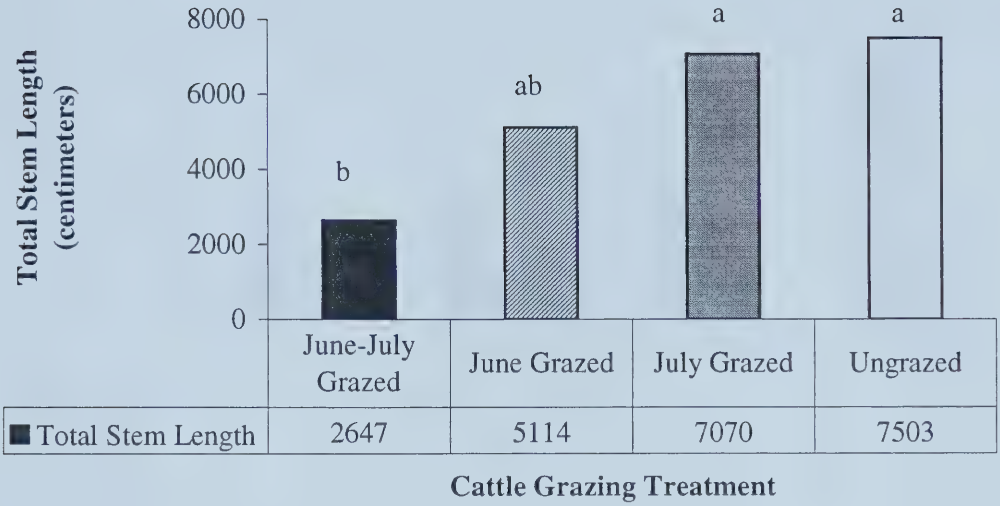


Figure 3-3. Effect of four grazing treatments on total aspen stem length (cm) after two years of application. Columns with different letters are significantly different ($p<0.05$).

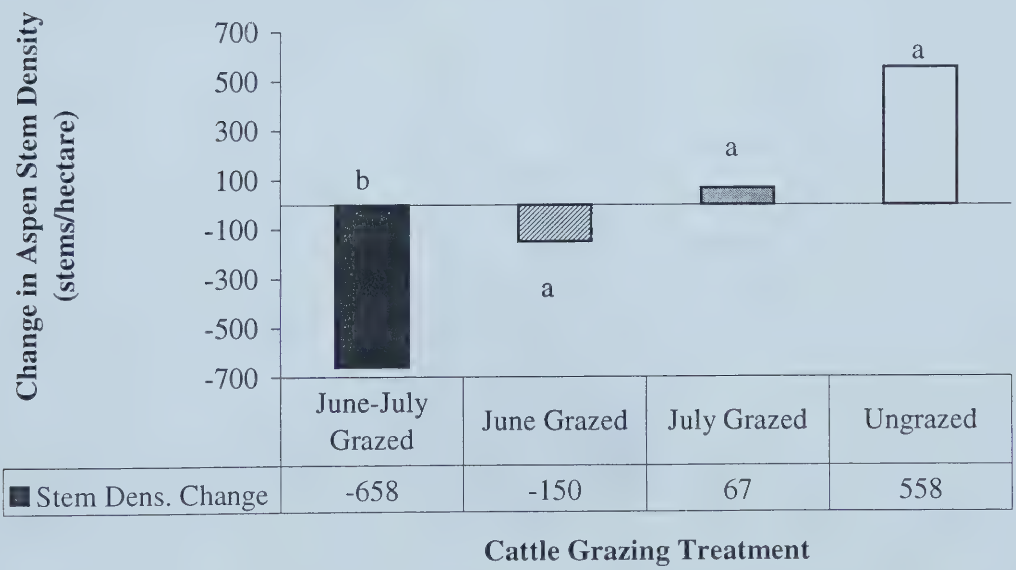
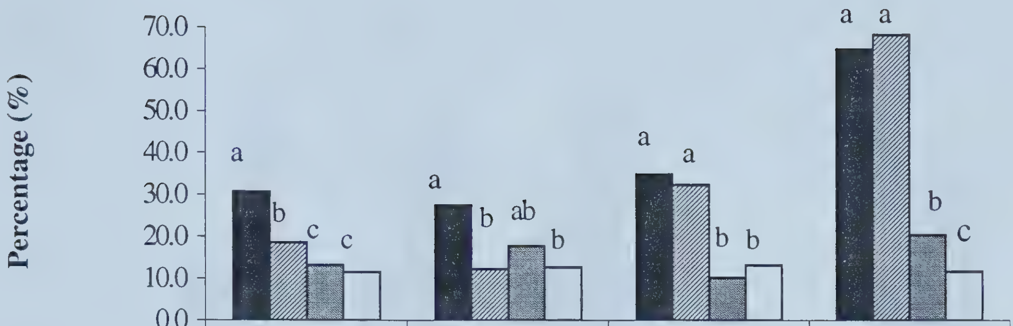


Figure 3-4. Effect of grazing treatment on change in aspen stem density (#/ha) after two years of application. Columns with different letters are significantly different ($p<0.05$)



	P-Dead	P-Dead(INJ)	P-Dead(NOINJ)	P-Injured
■ June&July Graze	30.7	27.5	35.0	65.0
▨ June Grazed	18.7	12.3	32.5	68.3
▩ July Grazed	13.2	17.8	10.3	20.5
□ Ungrazed	11.6	12.7	13.2	11.7

Figure 3-5. Effect of grazing treatment on percentage mortality (%), mortality (%) as a result of injury (INJ), mortality (%) without injury (NOINJ), and rate of cattle-induced injury (%) after two years of application. Columns with different letters are significantly different (p<0.05).

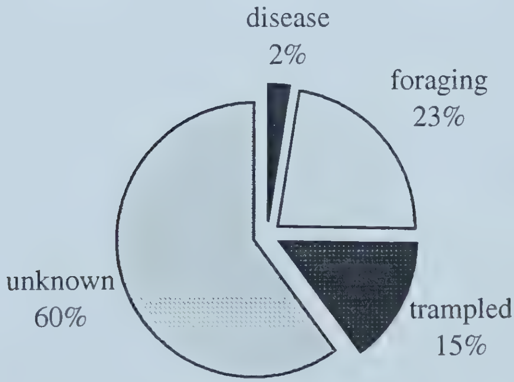


Figure 3-6. Summary of observed causes of aspen stem mortality during 1998 and 1999 growing seasons.

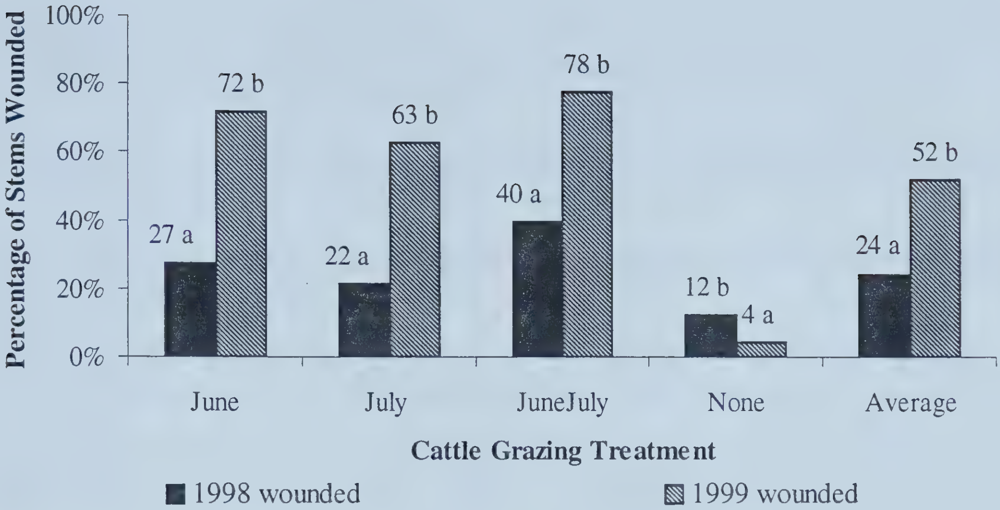


Figure 3-7. Comparison of aspen stem wounding by growing season (1998 vs. 1999) within cattle grazing treatment. Columns within treatment with different letters are significantly different ($p<0.05$).

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4.0 Seasonal Variation in Resistance of Aspen Stem Parts to Shearing Force

4.1 Introduction

Lane (1998) suggested that cattle consumption of trembling aspen corresponds with seasonal variation in aspen lignin content. Relationships among forage palatability, cellular lignin content, and stem resistance to shearing force have been examined in perennial ryegrass (*Lolium perenne*) (Inoue et al. 1989) and alfalfa (*Medicago sativa*) (Iwaasa et al.1996). Alfalfa stems have greater resistance to shearing force, and higher cellular lignin content later in the growing season. Similar patterns of stem lignification may occur in trembling aspen.

Lignin is added to tree stems via stem hardening, which is triggered by daily variations in ambient temperature (Lavender et al 1990). Hardening occurs when overnight temperatures are less than five degrees Celsius, but there is no frost. These conditions are often artificially induced by tree nurseries to produce more cold resistant seedlings. The majority of stem hardening occurs during late summer and early autumn (Lieffers 1998), when daytime temperatures remain warm, and nights are frost-free but relatively cool. Knowledge of stem hardening processes suggests that resistance of aspen stems to shearing force would increase later in the growing season.

4.2 Experimental Design

An investigation of aspen stem hardening was undertaken during the 1998 and 1999 growing seasons. Four stems were collected at each of five sites at 7-day (1998) and 14-day (1999) intervals throughout the growing season (late May – late September) to evaluate temporal variation in stem resistance to shearing force. Bud scars

distinguished current annual growth, 1-year old and two-year old stem parts from one another. After collection, the force required to shear current annual growth, 1-year old growth, and 2-year old growth stem parts was measured in pounds force using an Instron-1000. Pounds force was later converted to Newtons. Bernie Faulkner and Ian Buttar of the University of Alberta's Mechanical Engineering Department constructed a custom attachment for the Instron-1000 with assistance from Erin Dale, such that shear force could be applied to each age class of a suspended stem.

All trees utilized in this study were required to meet the following criteria: no visible damage, >80 centimeters in height, >2 years in age. No single aspen sucker was clipped more than once during the course of the study, thus all stems included in the study were of different above ground origin.

4.2.1 Measurements – Stem Resistance to Shearing Force

Measurements taken from stem clippings prior to use in the shearing force study included: stem diameters at each point of shearing (mm), leader lengths for current annual growth and 1-year growth (cm), plus total aspen stem height (cm) and root-collar diameter (mm). A plot script graphed shearing force values for each stem.

4.2.2 Data Analysis – Stem Resistance to Shearing Force

Data from 1998 and 1999 were treated separately due to the presence of a year effect. Subsequently, general linear modelling was performed for each group of data with and without stem part diameter as a covariate as follows:

$$Y_{ij} = B_i + T_j + D_{ij} + e_{ij}$$

Where: Y = Shearing Force (N) B = Block T = Julian Date

D = Date within Growing Season e = Experimental error

For all stem parts, statistical models that used stem part diameter as a covariate were stronger fits than the model without diameter as a covariate. Trend analysis established the presence of a positive linear effect of growing season date on shearing force for all stem parts during both 1998 and 1999. However, stem part diameter and shearing force required to sever a given stem part were inherently related, and both were expected to increase throughout the growing season. To assess the effects of date (adjusted for diameter) on shearing force (adjusted for diameter) the residuals of shearing force versus diameter were plotted against the residuals of growing season date versus diameter.

4.3 Results – Resistance to Shearing Force

4.3.1 Trembling Aspen Stem Resistance to Shearing Force

A positive linear effect of date on resistance to shearing force was identified for each stem portion tested (current annual growth, one-year old growth, two-year old growth) during both 1998 and 1999. When the covariate model was employed, no quadratic relationships were observed, but positive linear effects of growing season date remained strong. A positive linear effect of growing season date on shearing force was confirmed by plotting residuals of shearing force:diameter against residuals of growing season date:diameter. Plotting of current annual growth, one year old, and two-year old shearing force values indicated that observed hardening of each stem part during 1999 accounted for variation between final shearing force values of a particular stem part and initial shearing force values of the next oldest stem part (Fig. 4-4). Initial shearing force values for one-year old growth were comparable to season ending shearing force values for current annual growth (Table 4-1). Similarly, initial shearing force values for two-

year old growth were comparable to season ending shearing force values for one-year old growth.

Shearing force values more than doubled between late May and late September for current annual, one-year old, and two-year old stem parts (Table 4-1, Fig. 4-1, Fig. 4-2). Plot script value ranges for current annual, one-year old and two-year old stem parts were 5-500 N, 50-2500 N, and 500-5000 N respectively. Shearing force values of two-year old stem parts were dramatically greater than values for current annual or one-year old growth at each sampling date within each year (Fig. 4-4). Differences in shearing force values for current annual stem parts between 1998 and 1999 samples further indicated the presence of year to year environmental variation (Fig. 4-1).

Table 4-1. Mean shearing force (Newtons) required to sever three trembling aspen stem parts at beginning and end of 1999 growing season.

Stem	Current Annual Growth	1-Year Old Growth	2-Year Old Growth
25-May	11 N	266 N	1228 N
30-Sep	277 N	1528 N	2975 N

Shearing force for all stem parts was strongly correlated with growing season date. For current annual growth samples, shearing force ranged from 60 N to 300 N during 1998 and 10 N to 300 N during 1999 (Fig. 4-1). Shearing force of one-year growth ranged from ~200 N to ~1700 N during both 1998 and 1999 (Fig. 4-2). During the first week of September 1999, aspen resistance to shearing force was lower than predicted by linear regression (Fig. 4-1, Fig. 4-2).

4.4 Discussion

4.4.1 Stem Hardening and Shearing Force

Grazing preferences of cattle were most likely determined by two primary factors: forage availability and resistance of aspen stems to shearing force. Stem lignin content could explain seasonal differences in cattle utilization of trembling aspen (Lane 1998). Aspen shoots and leaves developed on site earlier in the growing season than grasses and forbs, rendering them a target for ungulate foraging. Lower utilization of aspen by cattle during July was likely associated with increasing shearing force required for cattle to sever aspen stems, decreased palatability of aspen stems, and an increase in alternate forage supplies.

Cattle likely had a greater impact on aspen stems during June because alternate forage was in short supply and resistance of aspen stems to shearing force was low. Studies of cattle diets show that grass and forbs are most preferred, but cattle utilize woody species when forage resources are limited (Hilton and Bailey 1974). Growth of herbaceous forage does not reach full capacity until early-mid July within the Lower Boreal Cordilleran ecoregion. Low levels of herbage biomass could have caused cattle to select trembling aspen in greater proportions during early June.

Cattle are known to graze aspen most intensely during early summer, and actively select current annual growth because shoots and leaves are very palatable (Bailey and Arthur 1985). This study also revealed high levels of aspen utilization early in the growing season, evidenced by higher stem wounding in the June grazed treatment relative to the July grazed treatment (Chapter 3).

4.5 Conclusions

Shearing force required to sever aspen stems increased throughout the growing season, while consumption of aspen stems by cattle decreased throughout the growing season. Cattle preference for aspen stems was negatively correlated with increased shearing force required to prehend stem parts. Cattle use of trembling aspen appeared to be limited by shearing force, as current annual growth was the preferred stem portion. Cattle did not utilize 2-year old aspen growth, and seldom utilized 1-year old aspen growth, suggesting they were incapable of severing these stem parts. Shearing force data and utilization patterns suggested that at shearing force values in excess of 100 Newtons cattle did not actively select aspen as a forage source. Aspen wounding rates were significantly higher during 1999 (Chapter 3), when shearing force resistance of current annual stem parts was dramatically lower than compared to 1998.

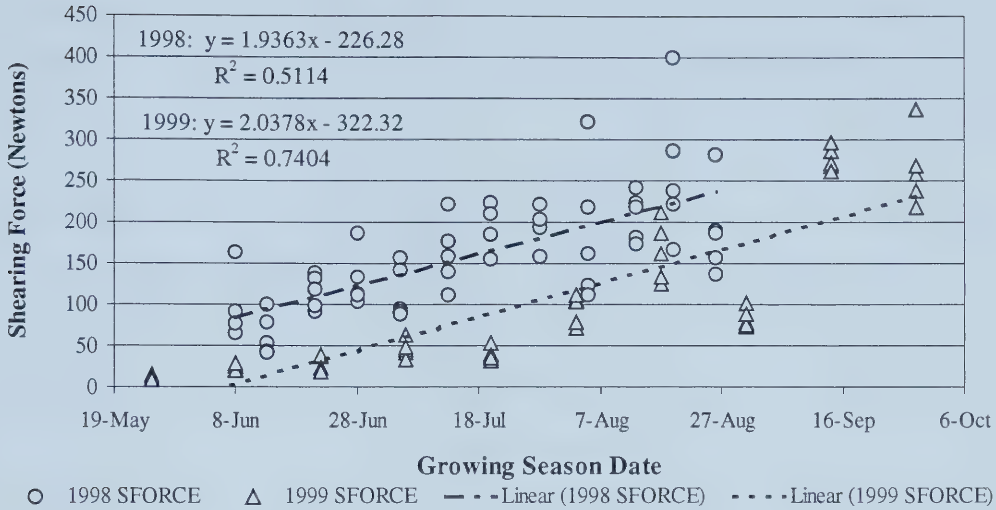


Figure 4-1. Effect of growing season date on shearing force (N) required to sever current-annual growth stem parts.

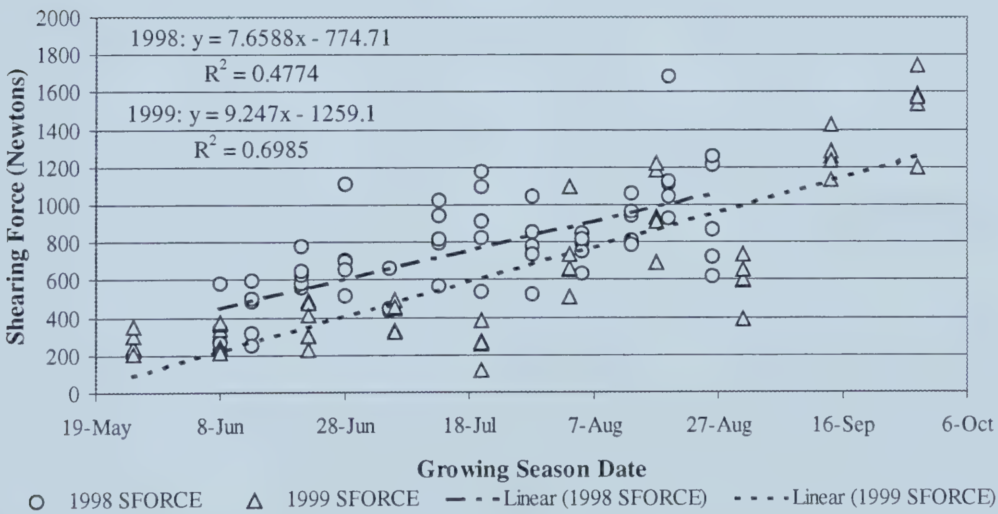


Figure 4-2. Effect of growing season date on shearing force (N) required to sever one-year old stem parts.

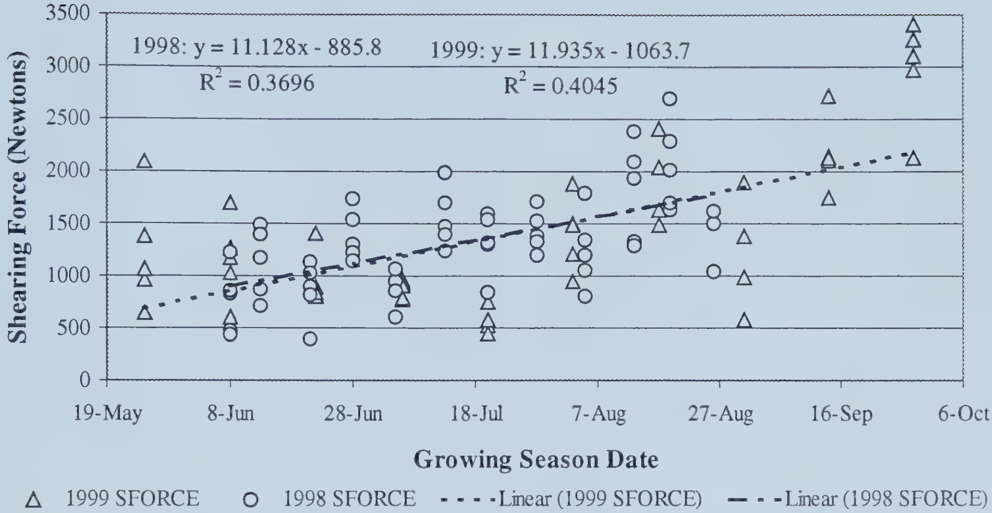
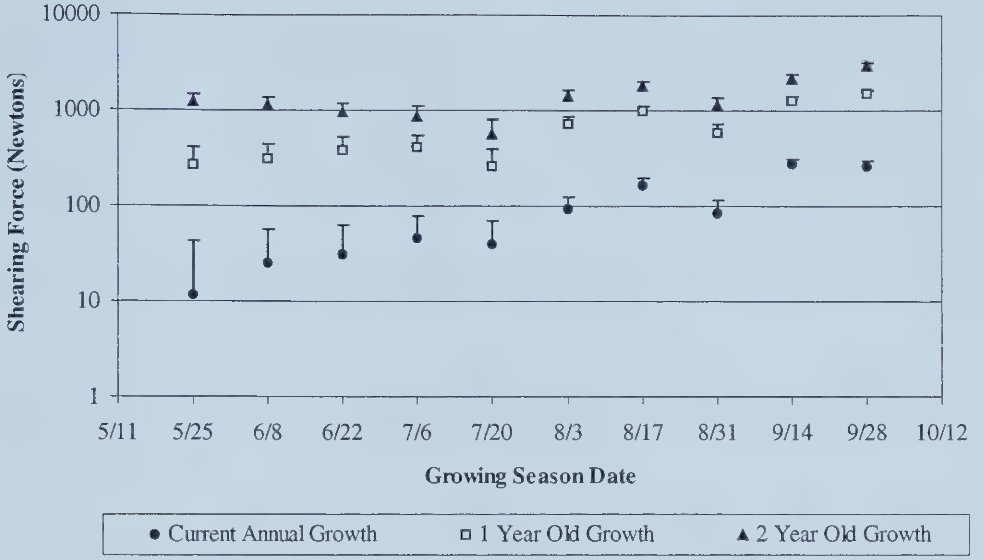


Figure 4-3. Effect of growing season date on shearing force (N) required to sever two-year old stem parts. 0



DATE	**5/25**	**6/8**	**6/22**	**7/6**	**7/20**	**8/3**	**8/17**	**8/31**	**9/14**	**9/28**
Stem										
CAG	11	25	31	46	40	94	164	83	277	264
1 Yr Old	266	307	382	410	258	731	988	597	1268	1528
2 Yr Old	1229	1151	950	874	576	1407	1810	1165	2171	2975

Figure 4-4. Effects of growing season date on mean shearing force (N) required to sever current-annual growth (CAG), one-year old, and two-year old stem parts during 1999 growing season.

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5.0 SYNTHESIS

5.1 Research Synthesis

At five years post harvest, the impacts of cattle and wild ungulate foraging on trembling aspen regeneration at this study location were evident. Regeneration of trembling aspen was attainable in the presence of cattle and wild ungulates. In this study, wild ungulate browsing had no significant impact on trembling aspen stem density or height. It was found that cattle grazing could dramatically reduce aspen regeneration within the lower boreal forest. After five years, aspen regeneration within the 2-year deferral treatment was not significantly different than the ungrazed treatment in either the early season or late season grazing systems. Similarly, cattle foraging did not reduce aspen stem density more than would be expected through natural thinning.

Season of grazing was the primary determinant of cattle impacts upon aspen regeneration in this study. At five years post-harvest, early season grazing had significantly reduced aspen stem height. Only two-year or permanent deferrals of cattle successfully reduced the impacts of cattle on aspen regeneration in early season grazing systems. However, cattle had no significant effect on aspen stem density or height within late season grazing trials (August-September) regardless of deferral treatment. Deferment of cattle grazing until August-September during each of the first five growing seasons following stand harvest reduced cattle impacts, and permitted successful establishment of a new aspen stand.

After three years of early season grazing (June-July) an attempt was made to reduce cattle impacts and identify the critical period during which cattle were most limiting to aspen stem growth. It was found that even after three years of severe foraging

impacts, aspen recovery was possible. Cattle foraging was most detrimental to aspen suckers during June. Continuous June-July foraging exacerbated the negative impacts of cattle on aspen regeneration. However, a 50% reduction in duration of cattle access to cut-blocks was successful in reducing the impacts of cattle foraging. The negative effects of cattle foraging on aspen regeneration were best mitigated by the elimination of June grazing.

Shearing force required to sever aspen stem parts increased substantially throughout the growing season, with the majority of hardening taking place after June. Stem lignin content was previously suggested as a primary factor affecting cattle utilization of aspen stems (Lane 1998, Bailey and Arthur 1985). Resistance of aspen stems to shearing force was low during June, thus stems were easier for cattle to consume, resulting in much higher aspen wounding rates. Increased resistance of aspen to shearing force later in the growing season appeared to reduce palatability and cattle utilization of trembling aspen shoots and leaves.

5.2 Resource Management Conflicts

Alberta's aspen dominated lower boreal forest is heavily impacted by a variety of industrial and recreational activities. Alberta's largest renewable resource based industries are presently at odds over the sustainability of aspen forests. Conflicts between livestock producers and forestry companies are currently prevalent. The presence of forest harvesting, livestock production and petroleum exploration in the boreal forest have complicated resource extraction. Efficient and effective management of recently harvested aspen stands in multiple use landscapes required specific knowledge of how cattle grazing affects aspen sucker growth and survival.

Traditionally, both cattle producers and forestry companies operated in single use landscapes. However, Alberta's publicly owned lands are managed with a multiple-use mandate, bringing resource extractors with single-use mindsets into conflict with one another regarding multiple-use practices. The forest company suspected that summer grazing of cut-blocks by cattle in the lower boreal forest impeded stand regeneration. Further, the forest company might be more susceptible to monetary penalties imposed by Alberta's government when establishment and regeneration standards are not met. The livestock producer viewed forest harvest schedules and practices as a threat to sustainable summer forage supplies on forest grazing leases. Given that cattle stocking rates of forest grazing leases are associated with forage biomass measurements from mature forest understory communities, the concerns of livestock producers regarding declining forage resources appear unfounded assuming that vigorous stand regeneration does not limit cattle access to forage resources.

5.3 Resource Management Policy

In May of 2000, Alberta Environment published new provincial establishment and regeneration standards for deciduous forests of the Lower Foothills Subregion. Recently, Alberta's government also outlined their continued commitment to sustainable resource management, and multiple-use landscapes. Curiously, differential forest establishment and regeneration standards were not formulated for single-use landscapes and multiple-use landscapes. Rather, the impacts of additional resource users on forest regeneration were assumed to be negligible and single-use standards were deemed appropriate for all public lands. Forests that fail to meet provincial establishment

standards (based on single-use landscapes) in multiple-use landscapes remain solely the responsibility of forestry companies.

Trembling aspen in the lower boreal ecosystem is a source of fiber production, but also a source of forage for wild and domestic herbivores, a provider of habitat for wildlife, and a provider of public recreation opportunities. Each of the aforementioned groups directly or indirectly impact aspen regeneration through various utilization practices. Alberta's commitment to multiple-use landscapes should be reflected in all policies that affect resource management on public land. Whether cattle grazing does or does not impact aspen growth and survival, the concept of multiple-use infers that the resource demands of all stakeholders are considered. Employment of single-use establishment and regeneration standards on multiple-use landscapes is clearly illogical.

5.4 Management Considerations and Recommendations

Alberta's government requires forest companies to ensure that timber operations do not reduce carrying capacity of the range for domestic livestock grazing (1994). However, it would be wise to consider when forage is available on forest grazing leases in addition to the quantity of forage available. Lack of early season foraging options could contribute to higher aspen utilization by cattle, especially during June. In prairie and parkland communities herbage growth cycles begin in mid-May, while biomass peaks during June (Irving 1992). However, initiation of herbaceous growth in boreal environments would occur later in the year due to the cooler climate, resulting in fewer forage options for livestock during June.

Elimination of June cattle grazing could dramatically reduce the impacts of cattle grazing on aspen growth and survival. Deferral of cattle access to cut-blocks until July

could enable aspen stem hardening and provide more palatable forage options for livestock. Rest rotation or rotational grazing systems could be employed to prevent repeated June grazing of one area in consecutive years. Uniform distribution of cattle was identified as the key to assuring sustainable aspen resources in multiple-use landscapes (Lane 1998).

In rest-rotation or rotational grazing systems, multiple paddocks would be created within a forested grazing lease using cross-fences. For rest-rotation grazing systems, cattle would be permitted to forage all but one paddock during each growing season, but would not graze any one paddock during the same time period in subsequent years. For rotational grazing systems, each paddock would be grazed during each growing season and at different points in subsequent growing seasons, but would not gain full relief from grazing pressure during any one year.

In either of these grazing systems, duration of cattle access to each paddock would be a function of herd size, paddock size, forage production and percentage of peak forage production at time of cattle entry into a particular paddock.

In both rest-rotation and rotational grazing systems heterogeneous landscapes could be partitioned into paddocks with more homogenous vegetation communities. In this manner, recently harvested areas could be assured relief from cattle grazing pressure during early summer. In addition, rotational grazing systems allow livestock managers to determine appropriate stocking rates for each paddock, further facilitating equitable distribution of cattle in cut-blocks and equitable utilization of forage resources.

Without proper grazing management, cattle congregate on and around logging roads and cut-blocks. Cross-fencing and simple rotational grazing systems are feasible

and should be most successful in achieving equitable grazing distribution. Timber producers could harvest stands at a smaller scale in a two-pass system. A cross-fence separating the mature forest from the recently harvested area could restrict cattle utilization of trembling aspen suckers during early summer. During June-July, cattle could graze the mature forest, making use of herbaceous under-story vegetation. In August-September, cattle could be moved to the harvested area, where they should actively select grasses and forbs that compete with aspen suckers for resources. In such a system, cattle would not have access to young trembling aspen stems when resistance to shearing force is low and susceptibility to foraging is high.

This rotational system could be employed for up to 5 years following stand harvest or as necessary, at which time the mature forest on the other side of the cross-fence could be harvested, and the grazing rotation switched. The aspen-sucker stand could be grazed during June-July, and the newly harvested area grazed during August-September. This management plan requires flexibility and cooperation from both cattle and timber producers, but should successfully reduce cattle utilization of trembling aspen stems in regenerating forests.

Other means of improving grazing distribution and reducing cattle damage to aspen stems do exist and may be desirable in some instances. Use of steers or yearling heifers, additional water provisions, or strategic salting locations could improve grazing distribution. Steers and yearling heifers showed greater curiosity and movement through forested landscapes than cow-calf pairs (McLean et al 1986). However, most of Alberta's cattle herd is comprised of cows, thus the use of steers and yearling heifers could be limited by gross number of animals (Irving personal communication 2001).

Provision of salt and water sources away from cut-blocks also has the potential to draw cattle towards low-use forage resources. Failure of public land managers and livestock producers to improve grazing distribution in cut-blocks threatens the sustainability of timber production.

Similarly, forest harvesting practices and schedules must be adjusted where possible to consider the needs of livestock producers. Winter harvesting of aspen stands would not disrupt summer grazing operations, while frozen soil rooting mediums would gain more protection against compaction and disturbance associated with harvesting methods (Lane 1998). In the long-term, timber producers and government policy makers must acknowledge reduced aspen growth rates resulting from multiple-use impacts, and extend stand rotation periods in order to sustain aspen resources.

5.5 Integrated Resource Management

Lane (1998) identified integrated resource management as essential to sustaining crown land multiple-use benefits. Knowledge of grazing-harvesting interactions must be combined with site-specific knowledge of plant communities, habitat availability, and animal behaviours to develop range management plans for forest grazing leases. It would also be beneficial to identify seasonal variations in forage availability, and adjust grazing schedules such that dependence on aspen as a forage supply is minimal. Sustainable management of aspen forests subject to forest grazing leases and deciduous timber licenses requires open communication and active cooperation among all resource users.

Given the current state of conflict between timber and livestock producers, it is unlikely that multiple resource extraction can be sustained at current intensities without adversely affecting aspen dominated ecosystems. Public land managers and policy

makers must consider the consequences of multiple land-use practices on each individual resource user. Until communication between relevant stakeholders is established the issues of forest harvest scheduling, livestock management, and differential scales of operation will not be adequately addressed.

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